Workload, psychosoziale sowie physiologische Erfassung von Stresserleben bei Studierenden im Alltag in einer Prüfungsphase im Vergleich zum Beginn des Semesters

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DISSERTATION

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ZUSAMMENFASSUNG

Im Zusammenhang mit der Umstellung auf das Bachelor-Master-System häuften sich Medienberichte über die gestiegene Belastung von Studierenden. Durch die Bologna Reform und die Umstellung auf das *European Credit Transfer System*, kurz ECTS – System, rückte die mit Studieren verbrachte Zeit immer mehr in den Interessensfokus. Bisherige Erhebungen der Studierzeit wurden aber zumeist retrospektiv, unter Angabe der Studierzeit in einer typischen Semesterwoche, vorgenommen (z.B. Multrus et al., 2008). Zur tatsächlich psychosozialen und physiologischen Belastung von Studierenden gibt es wenige Studien, die diese Belastungen im täglichen Leben in ihrer Variabilität und ihrem Zusammenwirken erfassen. Zumeist wurde der Stress von Studierenden über traditionelle Fragebögen erfasst (Robotham, 2008). Auch wenn hier Studien existieren, die Physiologie und subjektiv wahrgenommenen Stress in der Prüfungsphase untersuchen (z.B. Lacey et al., 2000; Spangler et al., 2002), so erfolgte die Erfassung meist nur zu wenigen Zeitpunkten im Semester. Studien, die in hoher Frequenz multimodal den Stress von Studierenden erfassen, gibt es wenige. Durch die hochfrequente multimodale Erfassung können Schwankungen über den Tag und ihre sozio-psycho-physiologischen Zusammenhänge dargestellt werden. Das Stress-Prozess-Modell von Schlotz (2019) liefert bei der Erfassung von Stress im Alltag von Studierenden eine Orientierungshilfe. Dabei werden zusätzlich zu Verhaltens-, affektiven und kognitiven Komponenten auch physiologische Komponenten der Stressantwort miteinbezogen. Im Modell von Schlotz (2019) sind nicht nur mögliche Zusammenhänge von psychologischen mit physiologischen Variablen, sondern auch moderierende Effekte physiologischer Faktoren, wie z.B. der Cortisol-Aufwach-Reaktion (*cortisol awakening response* = CAR), auf die Stressreaktion von Bedeutung. Eine veränderte CAR könnte als Resilienzfaktor Veränderungen in der Stressantwort erklären.

Ambulantes Assessment als Erfassungsmethodik bietet einige Vorteile gegenüber der traditionellen einmaligen Erfassung mittels Fragebögen. Soziale, emotionale, kognitive,

Verhaltens- und physiologische Prozesse können im täglichen Leben in Echtzeit mit elektronischen Tagebüchern, zumeist Smartphones, erfasst werden (Trull & Ebner-Priemer, 2013). Damit verbunden ist eine Erhöhung der ökologischen und externen Validität, da Verhalten in täglichen Situationen erfasst wird. Retrospektionseffekte werden durch häufige Abfragen innerhalb des Tages minimiert, sodass eine relativ unverzerrte Abbildung der Realität ermöglicht wird. Gleichzeitig können verschiedene Modalitäten, wie z.B. soziale Interaktionen, Bewertung von Situationen, affektive Reaktionen und physiologische Parameter, wie z.B. Blutdruck und Cortisol, erfasst werden. Dies ermöglicht das komplexe Zusammenspiel der verschiedenen Faktoren auf inter- sowie intraindividueller Ebene darzustellen und zu verstehen, um daran anschließend passende Interventionen zu gestalten. Durch die Analyse von Person x Situation-Interaktionen können diese Zusammenhänge aufgedeckt und die jeweiligen Interventionen auf bestimmte Personengruppen abgestimmt werden. Für diese intensiven Datenerhebungen mit Daten, die auf unterschiedlichen Analyseebenen erhoben werden, eignen sich hierarchisch lineare Modelle als statistisches Analyseinstrument besonders gut. Da in manchen Situationen im Alltag keine Datenerfassung möglich ist (z.B. beim Auto- bzw. Fahrradfahren), entstehen unvermeidbar fehlende Werte. Die Robustheit der hierarchisch linearen Modelle gegenüber fehlenden Werten, stellt einen weiteren Vorteil dieser Analysemethode dar.

Ziele der Dissertation sind die möglichst genaue Erfassung und Gegenüberstellung der Zeitnutzung von Studierenden hinsichtlich verschiedener Zeitnutzungskategorien, zu Beginn des Semesters und in der Prüfungsphase, um eine Schätzung der tatsächlichen Workload von Studierenden zu ermöglichen. Selbstregulatorische Prozesse, wie z.B. Stimmung, Motivation, Selbstkontrollfähigkeit und soziale Unterstützung werden beleuchtet, um Unterschiede im Lern- und Freizeitverhalten von Studierenden zu erklären. Weiterhin soll eine umfassende Darstellung der sozio-psycho-physiologischen Situation der Studierenden zu Beginn des

Semesters und während der Prüfungsphase erfolgen. Hierbei werden Stimmung, Stresserleben, Beanspruchung und Kontrollempfinden, Blutdruck, Blutdrucknachtabsenkung und die CAR zu Beginn des Semesters, den entsprechenden Werten während der Prüfungszeit gegenübergestellt. Zuletzt soll der Fokus auf psychophysiologische Interaktionen gerichtet werden. Hierbei wird eine mögliche Moderatorfunktion der CAR, bezogen auf die Stressreaktion beim Studieren, untersucht werden.

Ziel des ersten Manuskriptes war die Zeitnutzung von Studierenden, bzw. die Zeitnutzung möglicherweise beeinflussenden psychologischen Faktoren, genauer zu untersuchen. Bisher wurde die Zeitnutzung mit traditionellen Fragebögen, meist retrospektiv, mit einer Frage erfasst. Dazu wurde eine Studie unter Verwendung elektronischer Tagebücher durchgeführt. 154 Studierende gaben stündlich, über ihre gesamte Wachzeit, eine Woche zu Semesterbeginn und genau eine Woche vor einer Prüfung, ihre Zeitnutzung sowie ihre Stimmung ein. Motivationsprobleme, soziale Unterstützung und Selbstkontrolle wurden einmalig über Fragebögen erfasst. Der mittlere Workload war mit den Vorgaben der Bologna Reform übereinstimmend. Es zeigten sich jedoch große Unterschiede zwischen den Personen hinsichtlich der Zeit, die mit Studieren verbracht wurde, sowohl in der Prüfungsphase als auch zu Beginn des Semesters. Mit Hilfe hierarchisch linearer Modelle wurden inter- und intraindividuelle Zusammenhänge analysiert. Betrachtet wurden Zusammenhänge von Stimmung als intraindividueller Faktor und der mit Studieren, sowie mit aktiver und passiver Freizeitgestaltung verbrachten Zeit. Weiterhin gingen Zusammenhänge interindividueller Faktoren, wie Motivationsprobleme, soziale Unterstützung und Selbstkontrolle auf die Zeitnutzung, in die statistischen Modelle ein. Die Ergebnisse der Analysen zeigen die Wichtigkeit affektiver Faktoren, welche auf intraindividueller Ebene wirken. Vor der Studierzeit war die Stimmung schlecht und verschlechterte sich während der Zeit, in der studiert wurde, weiter. Wie erwartet standen Motivationsprobleme im Zusammenhang mit der

Studierzeit. Selbstkontrolle dagegen zeigte überraschenderweise keinen Zusammenhang mit der Studierzeit. Die Befunde des Semesterbeginns konnten in den statistischen Modellen der Prüfungsphase weitgehend repliziert werden.

Ziel der zweiten Untersuchung war es, den Stress, den Prüfungszeiten im Studium auslösen, zu untersuchen. Studien, die den Stress in Prüfungszeiten in Echtzeit im täglichen Leben der Studierenden erfassen sind selten und beschreiben oftmals nicht das gesamte komplexe Bild des Stresserlebens von Studierenden. Stimmung, aufgabenbezogener Stress, Beanspruchung, Kontrollempfinden und sozialer Kontakt wurden stündlich über die gesamte Wachzeit sowie Schlafqualität einmalig am Morgen erfasst. 154 Studierende füllten elektronische Tagebücher, für eine Woche zu Beginn des Semesters und eine Woche direkt vor einer Prüfung in der Prüfungszeit, aus. Zusätzlich wurde von der Hälfte der Studierenden über 24 Stunden der Blutdruck mittels ambulanten Blutdruckmessgeräten und die körperliche Aktivität mittels Bewegungssensoren erhoben. Bei der anderen Hälfte der Studierenden wurde Speichelcortisol an zwei aufeinanderfolgenden Tagen erfasst, um die CAR zu bestimmen. Die Daten wurden mit hierarchisch linearen Modellen ausgewertet. Die Prüfungsphase stand im Zusammenhang mit geringerer Gelassenheit, stärkerer negativer Valenz, höherem aufgabenbezogenen Stress, größerer Beanspruchung, geringerer wahrgenommener Kontrolle, weniger Sozialkontakt und einem größeren Bedürfnis alleine zu sein. Es konnten keine Unterschiede zwischen den beiden Zeitpunkten hinsichtlich wahrgenommener Energie, Zufriedenheit mit sozialen Interaktionen und Schlafqualität gefunden werden. Die Prüfungsphase war zudem mit geringerem systolischem Blutdruck verbunden, stand jedoch in keinem Zusammenhang zur Blutdrucknachtabsenkung. Die Prüfungsphase sagte einen geringeren Cortisolmorgenanstieg (AUCi - *area under the curve with respect to increase*) vorher, aber ein höheres Cortisolniveau direkt nach dem Erwachen (S1 – erster Cortisolwert nach dem Erwachen). Die Ergebnisse der Analysen deuten darauf hin, dass Prüfungsphasen mit dysphorischer Stimmung, Stress und sozialem Rückzug verbunden sind. Ferner deuten die Befunde auf eine Veränderung von physiologischen Prozessen in Phasen erhöhten universitären Stresses hin. Weitere Studien werden benötigt, um diese Befunde zu replizieren und auszuweiten. Die Ergebnisse weisen jedoch auf antizipatorische Stresseffekte und Effekte sozialen Rückzugs hin.

Die CAR war Ausgangspunkt der dritten Untersuchung. Studien zeigen Zusammenhänge der CAR mit verschiedenen Gesundheitsfaktoren sowie mit Risikofaktoren für bestimmte Erkrankungen (Miller et al., 2007). Eine schützende Funktion der CAR im Sinne einer Pufferfunktion des subjektiven Stressempfindens bei stressreichen Ereignissen konnte in einer Studie von Powell und Schlotz (2012) gezeigt werden. Die dritte Untersuchung legte ihren Fokus daher auf die moderierende Rolle der CAR hinsichtlich der Beurteilung des subjektiven Stressempfindens beim Studieren. Subjektives Stressempfinden und Studierzeit von 77 Bachelorstudenten wurden eine Woche zu Beginn des Semesters und genau eine Woche vor einer Prüfung mit elektronischen Tagebüchern erfasst. Zusätzlich wurden von den Studenten Cortisolspeichelproben, an zwei aufeinanderfolgenden Tagen in jeweils beiden Erhebungswochen, abgegeben. In den Analysemodellen wurden der erste Cortisolwert nach dem Erwachen (S1) und der Anstieg innerhalb der ersten Stunde nach dem Erwachsen (AUCi) als Cortisolindices verwendet. Stress zum Zeitpunkt davor, Aufwachzeit, Alter, Geschlecht und die Einnahme von Kontrazeptiva wurden als Kontrollfaktoren in die Modelle miteinbezogen. Es zeigte sich ein hochsignifikanter intraindividueller Zusammenhang zwischen Studierzeit und subjektivem Stressempfinden. Es konnte zudem eine signifikante Moderatorfunktion von S1 bzw. AUCi und Studierzeit auf das subjektive Stressempfinden gezeigt werden. Je höher der erste Cortisolwert nach dem Erwachen (S1), und je geringer der Cortisolanstieg am Morgen (AUCi), umso geringer der Zusammenhang zwischen subjektiven Stressempfindens und Studierzeit. Die Ergebnisse stehen in Einklang mit Studien, die Veränderungen von Reaktionen

auf subjektiven Alltagsstress als eine Funktion der CAR aufweisen. Die Richtung der Effekte scheint aber kontextspezifisch zu sein. Unterschiedliche Erklärungsansätze für die Befunde werden diskutiert und unterstreichen die Wichtigkeit neuer Studien, welche die Auswirkungen der CAR für die Stressregulation insbesondere beim Lernen von Studierenden untersuchen.

Auf der Grundlage bisheriger Studien und der Ergebnisse der eigenen Untersuchungen werden im zusammenfassenden Diskussionsteil neue Forschungsansätze im Bereich der Workload- und Stressforschung im universitären Bereich diskutiert. Eine differenzierte Betrachtung des Workloads im Rahmen der ECTS Vorgaben von Bologna wird vorgenommen, und den Workload beeinflussende Faktoren im Rahmen von Stressprozessen werden beschrieben. Die mögliche Bedeutung von Motivationsprozessen und beteiligten Emotionen sowie Sozialkontakten für die Stressentstehung innerhalb des universitären Lernsettings werden dargestellt. Die multimodale Erfassung des Stressentstehungsprozesses ermöglicht die Analyse von Interaktionen zwischen Kognitionen, Emotionen, Motivation und sozialen und physiologischen Prozessen. Drei Forschungsansätze dazu werden genauer ausgeführt. Diese betreffen die Rolle von Emotionen im Stressprozess, der Einfluss von Emotionen auf die Informationsverarbeitung und mögliche Einflüsse von physiologischen Prozessen im Kontext des Lernens.

INHALTSVERZEICHNIS

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Teile dieser Arbeit wurden publiziert oder zur Publikation eingereicht:

1. Koudela-Hamila, S., Grund, A., Santangelo, P., & Ebner-Priemer, U. W. (2019). Valence and motivation as predictors of student time use in everyday life: An experience sampling study. *Frontiers in Psychology 10:* 1430.

2. Koudela-Hamila, S., Smyth, J., Santangelo, P., & Ebner-Priemer U. W. (2020). Examination stress in academic students: a multimodal, real-time, real-life investigation of reported stress, social contact, blood pressure, and cortisol. *Journal of American College Health*. Online ahead of print: www.tandfonline.com.

3. Koudela-Hamila, S., Santangelo, P., Ebner-Priemer, U. W., & Schlotz, W. (submitted). Under which circumstances does academic workload lead to stress? Explaining intraindividual differences by using the cortisol-awakening response as a moderator. *Journal of Psychophysiology*.

1. EINLEITUNG

Stress im Studium wird häufig mit der Umstellung des Studiensystems auf das Bachelor-Master-System in Verbindung gebracht. Auch wenn diese Kopplung in der Realität angezweifelt werden kann, gibt es doch Gründe, warum eine Zunahme des Stresses unter Einführung des neuen Studiensystems eingetreten sein könnte.

1.1. Das Bachelor-Master-System und der Workload

Die Umstellung auf das Bachelor-Master-System in Deutschland hat den Fokus auf die Belastung von Studierenden und durch die Einführung des ECTS-Systems auf den Workload von Studierenden gelenkt. Die Einführung des ECTS-Systems bei dem der Workload einer Veranstaltung über die Höhe der Credits, die Studierende bekommen, entscheidet, hat eine objektive Bestimmung des Workloads notwendig gemacht (Groß, 2010). Die relativ selbstbestimmte Gestaltung des Studiums mit Veranstaltungswahlmöglichkeiten wurde durch ein weitgehend in der Planung festgelegtes Studium ersetzt.

Studien, die Workload erfassen, verwenden häufig nur eine Frage, die am Ende des Semesters gestellt wird und retrospektiv den Workload über das gesamte Semester erfasst (z.B. Multrus et al., 2008). Da der Workload aber starken Schwankungen unterworfen ist (Landrum et al., 2006; Ruiz-Gallardo et al., 2011), ist dieser Ansatz ungenau. Es konnte gezeigt werden, dass insbesondere Konstrukte, die starken Schwankungen unterliegen, anfällig für retrospektive Fehleinschätzungen sind (Trull & Ebner-Priemer, 2013). Wissenschaftlich fundierte Studien, die Workload in Verbindung mit dem Stressempfinden von Studierenden in ihrem Alltag dokumentieren, gibt es bisher nicht.

1.2. Akademischer Stress und bedingende Faktoren

Inwiefern die Veränderungen der Studienstruktur durch die Bolognareform auch zu einer Veränderung des Stressniveaus von Studierenden geführt haben, ist aufgrund des Fehlens von Studien, die dies direkt vergleichen, unklar. Studien zeigen jedoch Auswirkungen von Studienstress auf Affekt und Gesundheitsverhalten wie z.B. weniger Bewegung, schlechterer Ernährung, geringerem positiven Affekt und höherem negativen Affekt (Weidner et al., 1996). Es konnte zudem gezeigt werden, dass akademischer Stress im Zusammenhang mit verringertem Wohlbefinden (Xiang et al., 2019), geistigen (Stallman, 2010) und gesundheitlichen Problemen, geringerer Leistung, erhöhtem Risiko das Studium vorzeitig abzubrechen, Substanzmissbrauch und Schlafproblemen steht (z.B. Pascoe et al., 2020 für einen Überblick). Weiterhin konnten Harari et al. (2017) eine Reduktion von Sozialkontakten in Stressphasen aufzeigen. Als häufigste akademische Stressoren wurden in einer Studie von Stallman und Hurst (2016) akademische/kursbezogene Anforderungen, Studium-Lebens-Balance, Prokrastination und finanzielle Probleme angegeben.

Fragebogenstudien weisen auf einen positiven Zusammenhang zwischen akademischem Workload und Stress hin (siehe z.B. Kausar, 2010). Erhöhter Stress muss aber nicht zwangsläufig zu schlechterer Leistung führen. Das Yerkes-Dodson-Gesetz (nach Calabrese, 2008) nimmt einen umgekehrt U-förmigen Zusammenhang zwischen Anspannung und Leistung an. Die Leistung ist demnach im mittleren Anspannungsbereich am höchsten. Dies ist jedoch abhängig von der Aufgabenschwierigkeit: Bei leichten Aufgaben befindet sich das Leistungsmaximum im Bereich hoher Anspannung – bei schweren Aufgaben ist das Leistungsmaximum bei geringer Anspannung bereits erreicht (siehe Calabrese, 2008). Wenn also hoher Workload mit verstärkter Anspannung einhergeht könnte es, gerade im akademischen Bereich bei hoher Aufgabenschwierigkeit und hohem Arbeitspensum, zu Problemen kommen. Allerdings fehlen fundierte Studien zu den kognitiven Auswirkungen von Stress im universitären Setting.

Ein als hoch wahrgenommener Workload ist jedoch nicht als einzige Ursache für verstärktes Stressempfinden denkbar. Die Selbstbestimmungstheorie von Ryan und Deci

(2000) liefert Hinweise, warum der Wechsel des Studiensystems zu einer wahrgenommenen Überlastung der Studierenden führen könnte. Sie postuliert, dass die Motivation für ein Verhalten von der Befriedigung der drei folgenden Grundbedürfnisse abhängt: Autonomie, Kompetenzerleben und soziale Eingebundenheit. Werden diese Grundbedürfnisse erfüllt, äußert sich dies in erhöhter Motivation, welche mit erhöhter Kreativität, Problemlösefähigkeit, Durchhaltevermögen und verbessertem Wohlbefinden einhergeht. Wichtig für das Wohlbefinden ist nach Ryan und Deci (2000) somit die soziale Eingebundenheit als Grundbedürfnis. Dass soziale Eingebundenheit gerade im universitären Bereich wichtig ist zeigen Studien, die Zusammenhänge zwischen dem sozialen Netz von Studierenden und deren Stresserleben untersuchen (Lin, 2009). Ein weiteres Grundbedürfnis ist das des Kompetenzerlebens: Erlebt ein Studierender zu wenig Kompetenz wird er demotiviert und sein Wohlbefinden sinkt. Zusätzlich zu dem Grundbedürfnis des Kompetenzerlebens postuliert die Selbstbestimmungstheorie eine Verbindung zwischen Autonomie und Motivation. Die im neuen Bachelor-Master-Studiensystem festgelegten Strukturen könnten nach der Selbstbestimmungstheorie dazu führen, dass das Bedürfnis nach Autonomie und damit die intrinsische Motivation eingeschränkt wird, was zu einer Verschlechterung des individuellen Wohlbefindens und physiologischen Beeinträchtigungen führen könnte. Als intrinsisch motiviert wird Verhalten bezeichnet, welches nach Ryan und Deci (2000) durch das angeborene Bedürfnis entsteht, Neues zu lernen und Herausforderungen anzunehmen. Im Gegensatz dazu entsteht extrinsische Motivation z.B. durch sozialen Druck oder die Aussicht auf Belohnung (Deci & Ryan, 1993). Die vermehrte Bewertung von Leistungen sowie der Zeitdruck und die geringeren Wahlmöglichkeiten im Bachelor-Master-System könnten zu geringerer intrinsischer Motivation und damit zu Beeinträchtigungen führen (Deci & Ryan, 1993).

Studien konnten zeigen, dass Studierende, die intrinsisch motiviert sind, bessere Lernergebnisse zeigen, im Sinne von besserer Anpassungsfähigkeit an die Bedingungen an der

Universität, einer geringeren Stresswahrnehmung und erhöhter Ausdauer (Baker, 2004; Vallerand & Bisonnette, 1992). Umso alarmierender sind Studienergebnisse, die zeigen, dass die intrinsische Motivation über die Studiendauer an der Universität abnimmt (Pan & Gauvain, 2012).

1.3. Das Stress-Prozess-Modell

Die Selbstbestimmungstheorie (Deci & Ryan, 1993) gibt Hinweise auf Zusammenhänge zwischen veränderten Studienstrukturen, der Wichtigkeit sozialer Integration, und der Studienmotivation im Hinblick auf Workload und Stressentstehungsprozesse. Das Yerkes-Dodson-Gesetz (Yerkes & Dodson, 1908) bringt Stressprozesse in Zusammenhang mit Konsequenzen im Leistungsbereich, was zusätzlich zu den empirischen Befunden der gesundheitlichen Auswirkungen von Stress, die Wichtigkeit der Reduktion von Stress im universitären Bereich aufzeigt. Um Stressprozesse im Alltag zu verstehen, ist es zudem hilfreich sich den Stressprozess in seinen einzelnen Komponenten anzuschauen und zu analysieren. Darum wird im Folgenden das Stress-Prozess-Modell von Schlotz (2019), in dem die Prozesse der Stressentstehung, Konsequenzen und moderierende Einflussfaktoren beschrieben werden, näher erläutert.

Voraussetzung für die Wahrnehmung von Stress ist demnach das Auftreten eines Stressors. Der Stressor kann aufgabenbezogener oder sozialer Natur sein. Er kann durch die beruflichen Bedingungen oder die direkte Lebensumwelt der Person entstanden sein. In Anlehnung an die Theorie von Lazarus & Folkman (1984) kommt es im Modell von Schlotz (2019) aber nur dann zu Stress wenn, nach Auftreten eines Stressors, die Situation als relevant und potentiell gefährlich wahrgenommen wird und dabei die eigenen Ressourcen als zu gering eingeschätzt werden, um die Situation zu bewältigen. Eine stressende Situation im Studium könnte, z.B. ein erhöhter Workload sein, die für die eigene Person und die Zukunft als relevant eingeschätzt wird und die Ressourcen einer Person übersteigen. Dies deckt sich mit der

Definition von akademischem Stress nach Wilks (2008). Wilks (2008) definiert akademischen Stress über die Wahrnehmung, dass die akademischen Aufgaben die Ressourcen einer Person übersteigen.

Die Stressantwort geschieht nach Schlotz (2019) in vier verschiedenen Bereichen: Physiologisch, affektiv, kognitiv und auf Verhaltensebene. Physiologisch wird bei Stress die Hypothalamus-Hypophysen-Nebennierenrinden-Achse (engl. *Hypothalamic–Pituitary–Adrenal Axis*; HPA-Achse) und das autonome Nervensystem aktiviert. Die Aktivierung des autonomen Nervensystems kann sich z.B. durch eine Erhöhung des Blutdrucks (Kamarck et al., 2002) und der Atemfrequenz (Hernando et al., 2016) zeigen. Die affektive Komponente der Stressantwort kann sich z.B. in Anspannung und Nervosität äußern. Ein weiterer Bereich, in dem die Stressantwort erfolgen kann, sind kognitive Komponenten, wie z.B. Veränderungen von Exekutivfunktionen und Aufmerksamkeitsprozessen. Auf der Verhaltensebene kann es zu sozialem Rückzug oder auch schädigenden Verhaltensweisen, wie z.B. Alkoholkonsum oder verstärkter Kalorienzufuhr, kommen. Das Stress-Prozess-Modell von Schlotz (2019) fokussiert nicht nur die verschiedenen Systeme der Stressantwort, sondern auch moderierende Prozesse, welche individuelle Unterschiede in der Stressantwort erklären sollen. Als die Stressantwort moderierende Prozesse beinhaltet das Modell interindividuell unterschiedliche Reaktivität, Coping-Prozesse und Resilienzen. Unterschiede in der Reaktivität können nach Schlotz (2019) bereits früh im Stressprozess auftreten, wenn Personen den Stressor unterschiedlich bewerten, eine verstärkte Aktivierung des Stresszustands zeigen oder stärker auf den Stresszustand reagieren. Als zweiten Einflussfaktor auf den Stressprozess postuliert Schlotz (2019) Coping-Prozesse. Coping kann nach Lazarus und Folkman (1984, S. 141) definiert werden als kognitive Bemühungen oder Anstrengungen durch Verhalten, spezifische innere oder äußere Anstrengungen, zu bewältigen. Eine weitere Definition von Carver und Conner-Smith (2010) fokussiert sich mehr auf den Ansatzpunkt zur Stressreduktion und weniger auf die psychologischen Komponenten, die dafür benötigt werden. Coping bezeichnet nach Carver und Conner-Smith (2010) Bemühungen, die entweder darin bestehen die Bedrohung, den Verlust oder die Verletzung abzuschwächen bzw. ihr vorzubeugen oder die schädlichen Auswirkungen auf die Person zu minimieren. Nach Schlotz (2019) können Coping-Prozesse entweder willentlich oder automatisch ablaufen und zu individuell unterschiedlicher Intensität und Zusammensetzung der Stressantwort führen. Weiterhin können Coping-Prozesse die Auswirkungen von Stress auf die Gesundheit beeinflussen. Insbesondere Verhalten (z.B. Gesundheitsverhalten), aber auch physiologische Prozesse können im Sinne von Coping hilfreich oder auch in ihren Konsequenzen schädlich sein. Schlotz (2019) nennt in seinem Modell zwei Wege, die auf Ebene der Physiologie einen Versuch darstellen eine stressreiche Situation zu bewältigen, aber in ihrer Konsequenz negativ sein können: Eine verlängerte Stressantwort, sowie die Fehlregulation physiologischer Systeme. Der dritte Einflussfaktor auf den Stressprozess ist nach dem Stress-Prozess-Modell die Resilienz einer Person. Wenn eine Person trotz hohem Stress geringe bis gar keine gesundheitlichen Folgen zeigt, dann spricht man von einer hohen Resilienz, die diese Person aufweist. Resilienz kann aber bereits an einem früheren Punkt in der Stressentstehung den Stress mindern, indem sie die Intensität der Stressantwort einer Person verringert.

Das Stress-Prozess-Modell von Schlotz (2019) liefert konkrete Ansatzpunkte für die Erfassung von Stress und Stress moderierende Faktoren im Alltag. Die Erfassung von Stress kann nach dem Modell an drei Stellen im Stressprozess erfolgen – an der Stelle des Stressors, der Bewertung des Stressors oder der Stressantwort.

1.3.1. Psychologische Komponenten der Stressantwort: Änderungen in Kognition, Affekt und Verhalten

Die resultierende Stressantwort nach Auftreten eines Stressors kann auf verschiedenen Ebenen erfolgen. Nach dem Modell von Schlotz (2019) kann die Stressantwort sich auf vier verschiedene Bereiche erstrecken – drei davon sind psychologische Komponenten: das Verhalten von Studierenden (z.B. weniger Zeit mit Freunden verbringen oder Alkohol trinken), die Stimmung oder den Affekt (z.B. negativer Affekt, Nervosität) und Kognitionen (z.B. eine eingeschränkte Wahrnehmung).

Nicht nur die Unterscheidung der drei Bereiche der Stressantwort ist bei der Erfassung von Stress im Alltag von Bedeutung, sondern auch deren wechselseitige Zusammenhänge untereinander. So zeigen Studien Zusammenhänge von Affekt und Kognition. Curci et al. (2013) konnten beispielweise zeigen, dass negativer Affekt ruminative Prozesse fördert und die Arbeitsgedächtniskapazität verringert. Eine Änderung des Affektes könnte wiederum die Bewertung der Situation verändern, da Studien zeigen konnten, dass die Aktivierung ruminativer Gedächtnisinhalte in Zusammenhang mit der Wahrnehmung der Kontrollierbarkeit einer Situation steht (Lyubormirsky et al., 1999). Die Wahrnehmung der Kontrollierbarkeit könnte wiederum die Intensität der Stressantwort beeinflussen (Schmidt et al., 2015). Die Arbeitsgedächtniskapazität hat zudem Einfluss auf das Lernergebnis (siehe Alloway & Copello, 2013 für einen Überblick). Die große Zahl an denkbaren wechselseitigen Einflussmöglichkeiten betonen die Bedeutsamkeit der getrennten Erfassung und Analyse der wechselseitigen Beeinflussung affektiver, kognitiver und Verhaltenskomponenten im Stressentstehungs- und Stressaufrechterhaltungsprozess im Setting des universitären Lernens. Aber auch die physiologischen Komponenten nehmen eine wichtige Rolle im Stressprozess ein.

1.3.2. Physiologische Komponenten der Stressantwort: Blutdruck, Blutdrucknachtabsenkung und Cortisol

Physiologisch gibt es zwei unterschiedliche Systeme, die bei einer Stressantwort aktiviert werden: Das schnell reagierende autonome Nervensystem und das System der HPA-Achse, welches erst mit einer Zeitverzögerung von ungefähr 15-20 Minuten reagiert. Das sympathische Nervensystem, welches ein Teil des autonomen Nervensystems ist, ermöglicht eine Anpassung innerhalb weniger Sekunden an sich verändernde Bedingungen, insbesondere durch die Ausschüttung von Adrenalin und Noradrenalin („*fight-or-flight*“ Reaktion). Diese Reaktion auf Stressoren führt u.a. zu schnellen Änderungen im Blutdruck und in der Herzfrequenz.

Das Endprodukt der HPA-Achse ist das Glukokortikoidhormon Cortisol. Cortisol wird nach einer als stressig wahrgenommenen Situation ausgeschüttet und deswegen auch als Stresshormon bezeichnet. Cortisolrezeptoren finden sich in verschiedenen Teilen des Körpers, wodurch sich eine hohe Bandbreite an Einflussmöglichkeiten ergibt. Somit trägt Cortisol u.a. dazu bei den Blutfluss neu zu verteilen und das Gehirn und die Muskeln mit Energie zu versorgen (z.B. Fries et al., 2009). Die HPA-Achse besteht aus drei Komponenten. Der Hypothalamus schüttet Corticotropes Releasinghormon (CRH) aus, was wiederum bewirkt, dass die Hypophyse Adrenocorticotropes Hormon (ACTH) ausschüttet. Dies führt zu einer Freisetzung von Cortisol durch die Nebennierenrinde. Cortisol wiederum hemmt im Sinne einer negativen Feedbackschleife die Freisetzung von CRH und ACTH. Cortisol folgt einem tageszeitabhängigen Rhythmus. Es steigt in der zweiten Nachthälfte an und fällt dann, nach einem Hoch am frühen Morgen, den Tag über bis in die Nacht ab. In den ersten 20-30 Minuten nach dem Erwachen steigt der Cortisolspiegel stark an. Dies wird Cortisol-Aufwach-Reaktion (CAR) genannt. Die CAR ist von dem tageszeitabhängigen Verlauf zu unterscheiden. Sie unterbricht den linearen Trend des Cortisolanstiegs in den frühen Morgenstunden. Es gibt interindividuelle und intraindividuelle Unterschiede in der Form der CAR. Die Höhe der CAR wird mit der Reagibilität der HPA-Achse in Verbindung gebracht (Miller et al., 2007). Sowohl die CAR als auch die Stressantwort sind bei verschiedenen psychischen und körperlichen Erkrankungen verändert (Fries et al., 2009). Es wird angenommen, dass die CAR bei Stress zunächst adaptiv erhöht ist und dann in Folge abflacht, je länger die Stressreaktion andauert (Miller et al., 2007). In den frühen Arbeiten zur CAR wurde angenommen, dass die CAR einen relativ stabilen Biomarker darstellt, der sich hauptsächlich zwischen Personen unterscheidet (Pruessner et al., 1997). Weitere Studien zeigten aber, dass verschiedenen Schätzmodellen zufolge ein hoher Varianzanteil der CAR auf Schwankungen zwischen verschiedenen Erhebungstagen zurückzuführen ist. Der Anteil der Varianz, der auf Schwankungen zwischen den Tagen zurückgeführt werden kann, wird sogar höher eingeschätzt als der Anteil, der durch Unterschiede zwischen Personen erklärt werden kann (siehe Law et al., 2013 für einen Überblick). Law et al. (2013) führen Studien auf, die Zusammenhänge zwischen der CAR und verschiedenen Faktoren aufzeigen, die tagtäglichen Schwankungen unterworfen sind. Sie vermuten, dass die Flexibilität der CAR sogar relevanter für die psychosoziale Gesundheit sein könnte als die Höhe der CAR - ein Mangel an Flexibilität der CAR könnte somit eine Art Vulnerabilitätsfaktor darstellen, der eventuell aus einer Vielzahl an negativen Lebensereignissen resultiert und mit einer Zunahme an negativer Stimmung einhergeht (Law et al., 2013).

Nicht nur eine veränderte CAR, sondern auch ein erhöhter Blutdruck steht in Zusammenhang mit diversen Erkrankungen sowie einer erhöhten Mortalität (Conen & Bamberg, 2008). Hierbei ist nicht nur der Blutdruck über Tag von Bedeutung, sondern auch die Höhe des nächtlichen Blutdrucks (Yano & Kario, 2012). Die Absenkung des Blutdrucks in der Nacht, die sogenannte Blutdrucknachtabsenkung, wird mit der Erholungsfähigkeit von Personen in Verbindung gebracht (Rau, 2001). Die Blutdrucknachtabsenkung bezeichnet die Veränderung des Blutdrucks (BP) vom Tag zur Nacht in Relation zum durchschnittlichen Tagesmittelwert: Blutdrucknachtabsenkung (BPD) = [(Mittelwert (BP Tag) – Mittelwert (BP Nacht))/Mittelwert (BP Tag)] * 100 (Rau, 2004). Eine Blutdrucknachtabsenkung zwischen 10 und 20 Prozent wird als normal bezeichnet. Zusammenhänge der Blutdrucknachtabsenkung zu Morbidität und Mortalität wurden in Studien nachgewiesen (Conen & Bamberg, 2008; Yano & Kario, 2012). Wenn die Blutdrucknachtabsenkung vermindert ist, ist beispielsweise von einem erhöhten kardiovaskulären Risiko auszugehen (Middeke, 2005). Einmalige Messungen des Blutdrucks haben sich u.a. aufgrund des Weißkitteleffekts als wenig aussagekräftig erwiesen. Der Weißkitteleffekt bezeichnet eine Erhöhung des Blutdrucks aufgrund der Anwesenheit eines Arztes und tritt mit einer Prävalenz von etwa zehn Prozent auf (O'Brien et al., 2003). Auch der gegenteilige Effekt, einer maskierten Hypertonie, bei der der Blutdruck bei Anwesenheit eines Arztes geringer ausfällt als im alltäglichen Leben der Patienten kommt in 9-23 Prozent der Fälle vor (Pickering et al., 2002). So ist es nicht verwunderlich, dass zur diagnostischen Abklärung und Interventionskontrolle eine ambulante Blutdruckmessung über 24 Stunden im Alltag empfohlen wird (O'Brien et al., 2003). Weiterhin können durch die mehrmalige Erfassung des Blutdrucks im Alltag die Variabilität über Tag und Nacht sowie kurzzeitige Schwankungen erfasst werden, die für die Behandlung und Prognose genutzt werden können (Yano & Kario, 2012). Bei der Messung des Blutdrucks im Alltag spielt die Bewegungsaktivität einer Person für die Höhe des Blutdrucks eine große Rolle. Weiterhin ist der Blutdruck ein prominentes Beispiel dafür, dass es wichtig ist zwischen intra- und interindividuellen Zusammenhängen zu unterscheiden, denn diese können sich je nach Analyseebene in ihrer Richtung unterscheiden. Während eine Steigerung der Aktivität mit einem schnellen Blutdruckanstieg verbunden ist (*intra*-individueller Zusammenhang), haben Personen, die im Mittel sehr aktiv sind, einen niedrigeren mittleren Blutdruck (*inter*-individueller Zusammenhang). Dies gilt es in Studien, in denen psychophysiologische Zusammenhänge unter Verwendung des momentanen Blutdrucks analysiert werden, zu berücksichtigen.

Um die komplexen Veränderungen während einer Prüfungsphase im Vergleich zum Beginn des Semesters zu verstehen und diese angemessen beurteilen zu können ist es wichtig, sich verändernde Faktoren gemeinsam zu betrachten. So kann man einschätzen welche weiteren Einflussgrößen die untersuchte Veränderung mit verursacht haben könnten. Nicht nur das subjektive Stressempfinden hat Einfluss auf den Blutdruck (Landsbergis et al., 2013; Steptoe, 2000), sondern auch das Sozialverhalten (Rau, Georgiades et al., 2001; Rodriguez et al., 2008). Deswegen ist es wichtig eine Reihe weiterer möglicher Einflussfaktoren zusammen mit den physiologischen Daten zu erfassen.

1.3.3. Physiologische Stresskomponenten als mögliche Moderatoren der Stressantwort

Das Modell von Schlotz (2019) beinhaltet den Einfluss physiologischer Komponenten auf Stressprozesse. Da Cortisolrezeptoren häufig im Körper vorkommen sind nicht nur bidirektionale Einflüsse von Cortisol und psychischen Konstrukten denkbar, sondern auch eine moderierende Funktion von Cortisol auf psychische Prozesse. Psychophysiologische Zusammenhänge der CAR mit verschiedenen Stressmaßen konnten bereits nachgewiesen werden (Gartland et al., 2014; Kramer et al., 2019; O'Connor et al., 2013). Laborstudien liefern Hinweise auf diese Moderatorfunktion in Bezug auf die affektive Stressreaktion (Het et al., 2012; Het & Wolf, 2007; Kazén et al., 2012). Auch im Alltag konnten Zusammenhänge zwischen CAR Indices und einer verminderten Stimmungsverschlechterung unter Stress nachgewiesen werden (Powell & Schlotz, 2012). Im Gegensatz zu dieser Stimmungs-Puffer-Hypothese postuliert die Cortisol-Boost-Hypothese einen aktivierenden Effekt von Cortisol auf den menschlichen Organismus, der wiederum dazu führt, dass mit stressauslösenden Situationen besser umgegangen werden kann, was zu einer geringeren Stressantwort führt. Die CAR könnte somit Einfluss auf die affektive Stressreaktivität nehmen. Die affektive Stressreaktivität wiederum scheint ein Risikofaktor für das Auftreten von Depressionen zu sein. Studien konnten zeigen, dass Personen mit einer gegenwärtigen oder vergangenen Depression stärkere Stressreaktionen zeigen (Myin-Germeys et al., 2003; O'Hara et al., 2014; van Winkel et al., 2015). Weiterhin gibt es Hinweise darauf, dass die affektive Stressreaktivität depressive Symptome vorhersagen kann (Cohen et al., 2005; Parrish et al., 2011). Deswegen ist es wichtig die Faktoren zu identifizieren, die zu einer Veränderung der affektiven Stressreaktivität im täglichen Leben beitragen und so die Resilienz einer Person positiv beeinflussen (Kalisch et al., 2017; Southwick & Charney, 2012) bzw. die psychopathologischen Prozesse aufzuklären, die zur Entstehung einer erhöhten Stressreaktivität beitragen.

1.4. Ambulantes Assessment

Ambulantes Assessment bezeichnet die wiederholte computerisierte Erfassung von Selbstberichten, Verhalten, physiologischen Faktoren und Kontextfaktoren im Alltag in Echtzeit bzw. mit minimaler Verzögerung (Trull & Ebner-Priemer, 2013; Wilhelm & Perrez, 2013). Ambulantes Assessment bietet insbesondere bei der Analyse komplexer sozio-psycho-physiologischer Zusammenhänge gegenüber einer reinen Erfassung mit Fragebögen, welche Daten nur zu wenigen Zeitpunkten erfassen, klare Vorteile. Durch die Benutzung von Smartphones bei der Erfassung psychischer Konstrukte sowie Kontextfaktoren kann die Datenerhebung im täglichen Leben anstelle der Künstlichkeit im Labor geschehen, was mit einer höheren ökologischen und externen Validität verbunden ist. Ökologische oder externe Validität bezeichnet das Ausmaß, in dem die Ergebnisse einer Studie auf das Verhalten von Personen in ihrem alltäglichen Leben übertragen werden können (Wilhelm & Perrez, 2013). Weiterhin erfolgt die Erhebung der Daten in Echtzeit im Alltag von Personen, womit eine Minimierung von Retrospektionseffekten möglich wird. Zusätzlich kann der Zeitpunkt des Ausfüllens der Fragen mittels Smartphones kontrolliert werden. So konnte in einer Studie von Stone et al. (2002) gezeigt werden, dass Eintragungen in ein Papier-Bleistift Tagebuch zu einem späteren Zeitpunkt nachgetragen wurden. Das Papier-Bleistift Tagebuch war mit einem Lichtsensor ausgestattet, sodass genau registriert werden konnte, wann das Buch geöffnet wurde. Auch wenn in 94 Prozent der Fälle angegeben wurde, dass das Tagebuch zur richtigen Zeit ausgefüllt wurde, zeigte der Sensor, dass dies nur in 11 Prozent der Fälle tatsächlich der Fall war. Wenn Eintragungen zu einem späteren Zeitpunkt vorgenommen werden oder nur einmal mittels Fragebögen typisches Verhalten erfasst wird nutzen Personen häufig kognitive

Heuristiken, eine Art Daumenregeln, um ihre Eintragungen vorzunehmen. Der Abruf von Informationen unterliegt somit systematischen Verzerrungen, und ist z.B. abhängig von der Stimmung (*mood-congruency memory effect*), an welcher Position einer Reihe die Informationen stehen (*recency effect*) oder wie salient diese Informationen sind (*salience or novelty effect*) (Gigerenzer, 2008). Verzerrungen, die aufgrund der nachträglichen Einschätzung von Situationen resultieren, können unter Verwendung von Ambulantem Assessment als Datenerhebungsmethode minimiert werden.

Die Erfassung von Verhalten über elektronische Tagebücher ermöglicht weiterhin eine hochfrequente Erhebung von Daten im Alltag. Dadurch ist es möglich dynamische Prozesse über die Zeit zu beschreiben und intraindividuelle Prozesse zu untersuchen und diese getrennt von interindividuellen Prozessen zu analysieren. Mögliche Unterschiede in psychischen Prozessen zwischen Personengruppen mit bestimmten Merkmalen, auf Tagesebene oder zwischen verschiedenen Kontexten innerhalb eines Tages, können so bestimmt werden. Hierarchisch lineare Modelle liefern hier eine Analysemethode, welche die Schachtelung der Daten auf Personen-, Tages- und Situationsebene berücksichtigt und mit der intra- von interindividueller Varianz getrennt voneinander analysieren werden kann. Hierarchisch lineare Modelle sind weiterhin recht robust gegenüber fehlenden Werten, die bei einer Erfassung im Alltag nicht vermieden werden können (Raudenbush & Bryk, 2002).

Auch wenn Ambulantes Assessment viele Vorteile bietet, so gibt es auch eine Reihe an offenen Fragen und Herausforderungen, die in weiteren Studien geklärt werden sollten. So ist z.B. nicht klar in welchem Ausmaß bzw. in welcher Form die Messung an sich die erhobenen Daten beeinflusst. Allein die wiederholte Messung von Verhalten kann zu einer Verschiebung von Aufmerksamkeit führen. Ob aber dadurch Verhalten geändert wird ist fraglich, da es zu einer Verhaltensänderung mehr braucht als nur eine Aufmerksamkeitsverschiebung. Therapeutische Interventionen beinhalten nicht nur das Erfassen des Ist-Zustands, sondern auch eine Verhaltensänderungsmotivation auf Seiten des Patienten, Feedback zu erfasstem Verhalten, Analyse der Vorbedingungen und Konsequenzen, um nur ein paar Dinge herauszugreifen.

Studien, die Reaktivitätseffekte im Ambulanten Assessment untersuchen, kommen zu uneinheitlichen Ergebnissen (Barta et al., 2012). Beispielhaft seien hier drei Studien skizziert. Stone et al. (2003) untersuchten Reaktivitätseffekte in einer Stichprobe von 91 Schmerzpatienten, die randomisiert vier verschiedenen Bedingungen mit unterschiedlicher Abfragedichte (nur Fragebogen, drei, sechs oder zwölf Abfragen pro Tag) zugeordnet wurden. Am Ende der Woche sollten die Probanden die Schmerzintensität über die Woche einschätzen. Es konnten keine Reaktivitätseffekte bzgl. der Schmerzeinschätzung gefunden werden. Auch konnten keine Unterschiede zwischen den Gruppen bzgl. eines verbesserten Recalls nachgewiesen werden. Eine Analyse von Daten aus vier Studien von Shrout et al. (2018) mit Studierenden legt eine Erhöhung in der Einschätzung interner Zustände – vor allem negativer Zustände – und physischer Symptome zu Beginn einer Untersuchung nahe (*initial elevation bias*). In einer Studie von Conner & Reid (2012) zu Glücksgefühlen konnten keine Unterschiede zwischen Gruppen verschiedener Abfragefrequenzen (ein, drei, sechs Abfragen pro Tag) in einer Stichprobe mit 162 jungen Erwachsenen gefunden werden. Allerdings ergab sich ein Moderatoreffekt von depressiven Symptomen und Neurotizismuswerten: Bei Personen deren Werte hoch auf einem der beiden Moderatoren lagen, fand sich ein Rückgang der Glücksgefühle mit zunehmender Abfragefrequenz – bei Personen die niedrige Werte hatten, eine Zunahme an Glücksgefühlen mit der Zunahme an Abfragen. Wenn verschiedene Personengruppen unterschiedlich reagieren, stellt sich die Frage welche Faktoren der Messung bei welchen Personengruppen, welchen Einfluss haben. Auch die Fragestellung einer Untersuchung könnte als Kontextvariable die Angaben der Probanden verändern. Die Herausforderung bei der Durchführung von Studien mittels Ambulantem Assessment besteht darin, die für das zu messende Konstrukt bedeutsamen Faktoren des Kontextes, herauszufiltern und zu erfassen. Wobei als Kontext nicht nur die Messmethode, sondern auch Einflussfaktoren des Alltags zählen, die z.B. im Labor leichter kontrolliert werden können. Zu möglichen Einflussfaktoren auf die jeweilige Messung sind, wie bei Labor- oder Fragenbogenstudien jedoch auch, weitere Untersuchungen notwendig. Barta et al. (2012) empfehlen lineare Trends von Studienergebnissen, die Anzahl und Reihenfolge der Fragen, die Valenz der gemessenen Konstrukte, die Veränderungsmotivation und Einstellung der Probanden ggü. dem erfassten Verhalten sowie eine Einschätzung, ob fehlende Werte wirklich komplett zufällig fehlen (*completely missing at random*), anzugeben.

Hinsichtlich einer möglichst genauen Betrachtung des Workloads von Studierenden liefert Ambulantes Assessment den methodischen Zugang um hochfrequent und möglichst lückenlos Zeitnutzung zu erfassen. Somit können retrospektive Verzerrungstendenzen reduziert werden. Auch wenn es um die Beschreibung der sozio-psychologischen und physiologischen Stressantwort in einer Prüfungsphase geht, liefert die Methodik des Ambulanten Assessments Vorteile. Die Stressantwort kann in ihren verschiedenen Komponenten im Alltag der Studierenden in Echtzeit erfasst werden. Affektive und kognitive Komponenten im Stressprozess können mittels Smartphones erhoben werden. Physiologische Komponenten können zusätzlich aufgezeichnet werden und mit den psychologischen Daten in Verbindung gesetzt werden. Eine 24h-Blutdruckmessung kann ambulant im Alltag der Studierenden durchgeführt werden und Hinweise auf die Aktivierung des sympathischen Nervensystems und durch Bestimmung der Blutdrucknachtabsenkung Aufschluss über die Regenerationsfähigkeit des physiologischen Stresssystems geben. Bei der Erfassung von physiologischen Prozessen im Alltag ist die Kontrolle von möglichen Einflussfaktoren besonders wichtig, da z.B. Essverhalten und Aktivität direkten Einfluss auf körperliche Prozesse nehmen. Die Aktivität einer Person ist ein Faktor, die den Blutdruck maßgeblich beeinflusst und muss somit im Alltag bei Erfassung des Blutdrucks kontrolliert werden. Gemessen werden kann die Aktivität mit Hilfe von Aktivitätssensoren, die die Beschleunigung auf drei Achsen messen und in ein Beschleunigungsmaß integrieren.

Durch die Möglichkeit der Bestimmung der Cortisolkonzentration im Speichel kann Cortisol mehrmals am Tag ohne großen Aufwand erfasst werden. Somit kann der Cortisolmorgenanstieg über mehrere Tage hinweg bestimmt und mit den E-Diary Daten kombiniert werden. Dadurch besteht die Möglichkeit die Wirkzusammenhänge zu betrachten und diese auch auf unterschiedlichen Zeitebenen getrennt zu analysieren und somit schnelle tagesabhängige Schwankungen von langandauernden psychophysiologischen Prozessen zu unterscheiden.

Ambulantes Assessment bietet somit eine passende Erfassungsmethodik, um Stress im Alltag des Studiums genauer untersuchen zu können. Psycho-sozio-physiologische Prozesse und Stressoren, wie z.B. ein erhöhter Workload, können im Alltag von Studierenden in Echtzeit erfasst werden und einen möglichst unverzerrten Einblick in die komplexen Prozesse des Studienalltags geben.

2. FORSCHUNGSFRAGEN

Im Folgenden werden die verschiedenen Forschungsfragen hergeleitet, die den Analysen dieser Arbeit zu Grunde liegen.

2.1. Manuskript 1: Valence and motivation as predictors of student time use: An experience sampling study

Befragungen von Studierenden erfassen häufig nur den Gesamt-Workload pro Semester anhand rückblickender (retrospektiver) Fragebögen, die die Anzahl gearbeiteter Stunden in einer typischen Semesterwoche beinhalteten (Schulmeister & Metzger, 2011). Der Workload ist jedoch innerhalb eines Semesters starken Schwankungen unterworfen (Landrum et al., 2006; Ruiz-Gallardo et al., 2011; Tanner et al., 2008). Beispielsweise fällt zu Beginn des Semesters meist nicht viel Arbeit an, da die Prüfungen noch in weiter Ferne liegen, während direkt vor den Prüfungen der Workload und auch das Stressempfinden vermutlich ansteigt. Phänomene, die über die Zeit starken Schwankungen unterliegen, sind besonders anfällig für verzerrende Gedächtniseffekte (Trull & Ebner-Priemer, 2013). Personen benutzen sogenannte kognitive Heuristiken, eine Art Daumenregeln, um solche Beurteilungen der Arbeitszeit und des subjektiven Befindens in einer typischen Semesterwoche vorzunehmen. Studien zeigen beispielsweise, dass Personen sich besser an stimmungskongruente Inhalte erinnern (Gasper & Spencer, 2018).

Die erste Fragestellung hat zum Ziel die Zeit, die Studierende mit verschiedenen Aktivitäten verbringen, zu Beginn des Semesters mit der Zeit, die mit diesen Aktivitäten in der Prüfungsphase verbracht wird, gegenüber zu stellen. Dadurch soll insbesondere die Annäherung an eine objektive Schätzung des Workloads gelingen, da eine Woche mit wenig Arbeitsaufwand im Semester und eine Woche mit hohem Arbeitsaufwand in der Prüfungszeit zur Schätzung eines mittleren Workloads herangezogen werden. Da in der zweiten Fragestellung eine Gegenüberstellung der Zeiten mit wenig und hoher Belastung und zusätzlich die physiologische Belastung in Zeiten hoher Arbeitsbelastung für die Studie von Interesse waren, wurden hierzu nicht die Wochen mit mittlerem Arbeitsaufwand im Semester zur Bestimmung des Workloads herangezogen.

Bei der Erfassung des Workloads mittels elektronischer Tagebücher sind fehlende Werte unvermeidbar, da es im Alltag, z.B. beim Auto- oder Fahrradfahren, nicht möglich ist das E-Diary (elektronische Tagebuch) auszufüllen. Bei der Schätzung des Workloads eines Semesters wird ein Verfahren benötigt um diese fehlenden Werte zu schätzen. Denn fehlende Werte tragen zur Reduktion des Gesamtsummenwertes des Workloads bei und führen somit zu einer systematischen Unterschätzung des Workloads. Auf Basis der erhobenen Daten wird zur Beantwortung der Frage nach dem Gesamt-Workload ein Schätzmodell hergeleitet, um die fehlenden Werte zu schätzen. Mit Hilfe dieses Schätzmodells wurden nicht nur die fehlenden Werte der Studierzeit geschätzt, sondern auch die der weiteren erhobenen Zeitbudgetwerte, wie z.B. der aktiven und passiven Freizeitgestaltung.

Durch die Erfassung mit E-Diaries können Zusammenhänge verschiedener Konstrukte über die Zeit innerhalb von Personen untersucht werden. Somit treten innerpsychische Prozesse in den Vordergrund des Forschungsinteresses, im Gegensatz zu Zusammenhängen verschiedener Konstrukte zwischen Personen, welche mit traditionellen Fragebögen im Querschnitt erfasst werden. Studien finden nicht nur eine starke Schwankungsbreite innerhalb des Semesters in der mit akademischen Inhalten verbrachten Zeit (Landrum et al., 2006; Ruiz-Gallardo et al., 2011), sondern auch hohe Unterschiede zwischen Personen (Kember et al., 1996; Runyan et al., 2013; Schulmeister & Metzger, 2011; Stinebrickner & Stinebrickner, 2004). Daraus ergibt sich die zweite Fragestellung des ersten Manuskriptes nach bedingenden Faktoren der unterschiedlichen Zeiteinteilung. Studien weisen auf die Wichtigkeit selbstregulatorischer Aspekte von Verhalten hin (Senécal et al., 1995; Weinstein et al., 2011). Als für die Selbstregulation wichtige Variablen wurden Selbstkontrolle, Motivation, Stimmung und soziale Unterstützung als Prädiktoren von Studierzeit sowie aktiver und passiver Freizeitgestaltung herangezogen, um zu prüfen, ob diese selbstregulatorischen Aspekte die hohe Varianz in Studierzeit bzw. aktiver und passiver Freizeitgestaltung erklären.

2.2. Manuskript 2: Examination stress in academic students: A multimodal, real-time, real-life investigation of reported stress, social contact, blood pressure and cortisol

Bisherige Studien, welche verschiedene Komponenten der Stressantwort insbesondere in der Prüfungsphase untersuchen sind häufig (Brose et al., 2017; Juth et al., 2015). Allerdings beleuchten sie meist nur eine Facette der Stressantwort, wie z.B. die Auswirkungen auf den Cortisolspiegel (Duan et al., 2013). Zudem werden auf der psychologischen Ebene oftmals nur das subjektive Stressempfinden oder die Prüfungsängstlichkeit erfasst – beides wichtige Komponenten, aber nicht die einzigen Einflussfaktoren. Weiterhin wurde in bisherigen Studien vernachlässigt, verschiedene psychologische Konstrukte, wie z.B. sozialen Kontakt, Schlaf, Stimmung und Stress zu erfassen, welche sich alle in der Prüfungsphase verändern und sich aber auch gegenseitig beeinflussen können. Auch der wechselseitige Einfluss der psychologischen Konstrukte mit physiologischen Faktoren, speziell in der Prüfungsphase von Studierenden, wurde bisher kaum untersucht. Da viele verschiedene psychologische und physiologische Faktoren sich in der Prüfungsphase im Vergleich zum Semesterbeginn vermutlich in einem recht ähnlichen Zeitfenster verändern, ist es wichtig diese Faktoren in ihrer Gesamtheit zu betrachten und mehrmals in diesem Zeitraum der Prüfungsvorbereitung zu erfassen. Studien, welche die Veränderungen von physiologischen Prozessen in einer Prüfungsphase untersuchten, kamen zu unterschiedlichen Ergebnissen (Duan et al., 2013; Vedhara et al., 2000; Weik & Deinzer, 2010). Diese Unterschiede in den Ergebnissen könnten in unterschiedlichen Messintervallen und Messzeiträumen, unterschiedlichen Messverfahren und fehlender Kontrolle beeinflussender Variablen begründet sein.

Zu den physiologischen Systemen, die durch wahrgenommen Stress beeinflusst werden, zählt u.a. der systolische und diastolische Blutdruck. Studien im Bereich des ambulanten Assessments konnten signifikante Zusammenhänge zwischen Stimmung und Blutdruck finden (Steptoe, 2000; Steptoe et al., 2007; Steptoe & Wardle, 2005; Zawadzki et al., 2016). Um eine Kopplung der Blutdruckdaten mit den Daten des E-Diaries im Alltag zu ermöglichen sowie eine reliable und prädiktive Schätzung des mittleren Blutdrucks zu erhalten, wurde dieser über 24 Stunden erfasst. Studien zeigen eine Überlegenheit der prädiktiven Validität der 24h-Blutdruckmessung gegenüber einer einmaligen Messung beim Arzt (Yano & Kario, 2012). Wird der Blutdruck über mehrere Male am Tag und in der Nacht erfasst, ist es weiterhin möglich die Variabilität des Blutdrucks oder auch die Blutdrucknachtabsenkung zu bestimmen. Die Blutdrucknachtabsenkung stellt ein Maß der Regenerationsfähigkeit einer Person dar (Papousek et al., 2010; Rau, 2004). Bei zu niedriger Blutdrucknachtabsenkung wird eine gestörte Regeneration im Schlaf angenommen. Somit kann die Blutdrucknachtabsenkung als ein Indikator der Regenerationsfähigkeit von Studenten, gerade unter hoher Arbeitsbelastung, herangezogen werden. Da eine wichtige Einflussgröße auf den Blutdruck im Alltag die Bewegungsintensität darstellt, wurden für die Studie Bewegungssensoren verwendet, um eine Messung der alltäglichen Aktivität zu ermöglichen.

Einen weiteren physiologischen Parameter, der mit wahrgenommenem Stress, Burnout und verschiedenen psychischen Erkrankungen in Verbindung gebracht wird, stellt die CAR dar. Studien zeigen, dass die CAR u.a. bei Depression und Burnout verändert ist (siehe z.B. Miller et al., 2007). Es wird angenommen, dass zuerst erhöhte Werte der Aufwachreaktion resultieren, sich das System der HPA-Achse somit versucht an die höheren Anforderungen anzupassen, es aber dann zu einem Zusammenbruch des Systems mit niedriger CAR kommt (Miller et al., 2007). Es konnten auch Zusammenhänge zwischen der CAR und verschiedenen Stressmaßen gefunden werden (Gartland et al., 2014; Kramer et al., 2019; O'Connor et al., 2013). Insofern können Veränderungen der CAR unter Stress auf mögliche Beeinträchtigungen im physiologischen Bereich hinweisen, die durch anhaltenden Stress bedingt sind.

Psychologisch ist für die Veränderungen in der Arbeitsbelastung der Studierenden nicht nur das subjektive Stresserleben im Alltag interessant. Als weitere Einflussgrößen auf das Stresserleben wurden, zusätzlich zum wahrgenommenen Stress gemäß dem Demand-Control-Modell von Karasek (1979), die wahrgenommene Beanspruchung und das wahrgenommene Kontrollempfinden bei der Studie miterfasst. Weitere für den Stressprozess wichtige Variablen, wie die Schlafqualität und die Stimmung, anhand der drei Dimensionen Ruhe, Wachheit, Valenz (Wilhelm & Schoebi, 2007), wurden in den Vergleich der zwei Untersuchungszeiträume miteinbezogen.

Ziel der zweiten Analyse war es die Gesamtheit der psychosozialen und physiologischen Veränderungen im Alltag mithilfe des Ambulanten Assessments in einer Prüfungsphase im Vergleich zum Beginn des Semesters, auf den drei Ebenen Physiologie (Blutdruck und CAR), Psychologie (u. a. Stresserleben, Schlafqualität) und Sozialverhalten (Häufigkeit von Sozialkontakten und Bewertung der Sozialkontakte) darzustellen.

2.3. Manuskript 3: Under which circumstances does academic workload lead to stress? Explaining intraindividual differences by using the cortisol-awakening response as a moderator

Nach der Darstellung von Unterschieden beim Vergleich des Semesterbeginns mit der Prüfungsphase auf den drei oben dargestellten Ebenen stellt sich nun die Frage nach Variablen, die eventuell den Stressprozess moderieren. Das Stress-Prozess-Modell (Schlotz, 2019) nimmt an, dass interindividuelle Unterschiede im Coping-Verhalten, in der Stressreaktivität oder auch in der Resilienz, den Stressprozess an unterschiedlichen Stellen beeinflussen. Laborstudien konnten eine moderierende Funktion der CAR auf affektive Stressprozesse nachweisen (Het et al., 2012; Het & Wolf, 2007; Schlotz et al., 2008). Zudem konnten Hoyt et al. (2016) in einer

E-Diary Studie zeigen, dass Zunahmen in momentanem Cortisol mit höherer Aktiviertheit, Aufmerksamkeit und Entspannung und einem Trend hinsichtlich weniger Stress und Nervosität verbunden waren. Dies interpretieren sie im Sinne der Cortisol-Boost-Hypothese, nach der die Erhöhung des Cortisols es ermöglicht besser mit Stressoren umzugehen, sodass weniger Stress und Nervosität resultieren. Auch wenn die Studie von Hoyt et al. (2016) mit E-Diaries durchgeführt wurde, so bezieht sie sich aber auf momentane Anstiege im Cortisolspiegel und nicht auf die CAR. Die CAR-Puffer-Hypothese hingegen bezieht sich auf den morgentlichen Cortisolanstieg (CAR) und postuliert eine Moderatorfunktion der CAR im Sinne einer geringeren Stimmungsverschlechterung nach Stress bei hoher CAR. Studien deuten darauf hin, dass die CAR der Vorbereitung auf die Anstrengungen des Tages dient (Stalder et al., 2016). So könnte eine erhöhte CAR eine erleichterte Anpassung an Stressoren mittels geringerer Stressantwort ermöglichen. Powell & Schlotz (2012) untersuchten in einer E-Diary Studie tagesspezifische regulatorische Effekte der CAR auf die Stresseinschätzung und konnten einen Puffer-Effekt der CAR finden. Powell & Schlotz (2012) untersuchten den Effekt von Stressempfinden auf Stimmung. Ob sich dieser Effekt auch im Lernkontext unter Verwendung des Stressors Lernzeit auf die Stresswahrnehmung nachweisen lässt war Ziel der dritten Analyse dieser Arbeit. Die moderierende Wirkung der CAR auf den Zusammenhang zwischen Studierzeit und Stressempfinden wurde analysiert. Weiterhin deuten Studien darauf hin, dass es einen Unterschied im Stressprozess zwischen Zeiten mit hohem vs. niedrigem Backgroundstress gibt (siehe Gump & Matthews, 1999 für einen Überblick). Als zweite Fragestellung ging deswegen mit ein, ob es Unterschiede in der CAR Moderatorfunktion gibt, wenn Semesterbeginn und Prüfungsphase miteinander verglichen werden.

3. MANUSKRIPTE

3.1. Manuskript 1: Valence and motivation as predictors of student time use in everyday life: An experience sampling study

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Abstract

Popular descriptions of studying frequency show remarkable discrepancies: students complain about their workload, and alumni describe freedom and pleasure. Unfortunately, empirical evidence on student time use is sparse. To investigate time use and reveal contributing psychological factors, we conducted an e-diary study. One hundred fifty-four students reported their time use and valence hourly over seven days, both at the start of the semester and during their examination period. Motivational problems, social support and self-control were assessed once via questionnaires. Whereas the mean academic time use was in the expected range, the between-subject differences were substantial. We used multilevel modeling to separately analyze the within- and between-subject associations of valence as within factor and time use and social support, self-control and motivation as between factors and time use. The analyses revealed the importance of affective factors on a within-subject level. Before studying, valence was already low, and it deteriorated further during studying. As expected at the between-subject level, motivational problems were related to less time studying, whereas surprisingly, self-control had no effect. The findings at the start of the semester were replicated in the examination period.

3.1.2. Introduction

There are remarkable discrepancies in people's descriptions of studying. Whereas students complain about their workload and stress, alumni describe how much they enjoyed studying and were motivated by their freedom of choice in terms of topics and courses, personal time management, and learning with other students. The latter reports support psychological and educational models and theories that link self-regulated learning to greater motivation and positive affect (Zimmerman, 2008). However, empirical evidence based on methodologically sound studies is limited, especially regarding how academic time use (i.e., time use for learning-oriented activities and course attendance) is influenced by psychological mechanisms such as valence, motivation and self-control.

The importance of assessing academic time use has been addressed frequently in research studies (Marshall, 2018; Scully & Kerr, 2014; Stinebrickner & Stinebrickner, 2004). However, the methodological quality of these studies has often been questioned. The criticisms concern the accuracy of time use assessments, with some researchers stating that academic time use fluctuates over the course of a semester (Landrum, Turrisi, & Brandel, 2006; Ruiz-Gallardo, Castaño, Gómez-Alday, & Valdés, 2011; Stinebrickner & Stinebrickner, 2004) and that pure retrospective assessments are also problematic (Stinebrickner & Stinebrickner, 2004). In Europe, the required academic workload was specified by the Bologna reform and was set at 40 h/week. As accreditation bodies review these calculations, the effort to assess academic time use properly has further increased.

Fortunately, recent technological advances have facilitated investigating academic time use and the accompanying psychological processes prospectively in daily life. Different terms have been used to assess data in real time in daily life with these new technologies, including ambulatory assessment (Fahrenberg, Myrtek, Pawlik, & Perrez, 2007), ecological momentary assessment (Stone & Shiffman, 2002), and experience sampling method (Csikszentmihalyi &

Larson, 1987). The experience sampling method (ESM) has several major advantages over measuring only once with paper-pencil questionnaires. Time use and psychological states can be captured repeatedly in everyday life in real time, thereby enabling the investigation of within-person psychological processes that may influence academic time use and avoid recall bias. Unfortunately, processes that dynamically fluctuate over time are even more prone to recall bias (Trull & Ebner-Priemer, 2013). Accordingly, academic time use, which varies considerably over an entire semester as demands change such as during the examination period (Landrum et al., 2006; Ruiz-Gallardo et al., 2011; Tanner, Stewart, Maples, & Totaro, 2008), should be assessed with methods that are not prone to retrospective distortions.

In the past, paper-pencil diary studies have been used to investigate academic time use. However, accuracy of paper diaries has been questioned, as electronic timestamps are not possible. Using an electronically manipulated paper diary, Stone, Shiffman, Schwartz, Broderick, and Hufford (2002) found backfilling in 89% of all data entries. Backfilling might increase inaccuracy and might explain, in part, the wide range of absolute numbers of academic time use, ranging from 28.3 h (Nonis, Philhours, & Hudson, 2006) to 50 h (Kember, NG, TSE, Wong, & Pomfret, 1996) per week in paper diary studies. Nevertheless, paper diaries might be superior to one-shot questionnaires, even though empirical evidence to support this assumption is still lacking. More recent studies use e-diaries to prevent backfilling, but to our knowledge, only three studies exist that have assessed academic time use via an electronic approach. Runyan et al. (2013) investigated the time use of undergraduate students at a Midwestern university in the US using an e-diary. The students received prompts at random times five to seven times a day between 6:00 a.m. and 11:00 p.m. Unfortunately, the assessed timeframe was time use over the last 20 minutes. Therefore, rather than covering the entire day of student time use, the study only examined the preceding 20 minutes of 5 to 7 episodes. Schulmeister and Metzger (2011) assessed time use via an online tool on which extensive backfilling was restricted electronically. They investigated daily time use in a semester over five months in a sample of undergraduate students. In the study, data from 18 samples from 13 different faculties at five different universities in Germany resulted in an overall academic time use of 20–27 h/week, which was far below the requested workload of 40 h/week (Metzger & Schulmeister, 2011). In a study by Marshall (2018) time use of 111 students from four different faculties at the University of New Zealand over two typical semester weeks without any deadlines was assessed. The students had to record their time use every evening on an electronic platform so that backfilling was prevented electronically. Students' average time spent studying was 42.3 h on the first week and 40.9 h on the second week with high between-subject variability (min 13.5 h and max 82.0 h).

Considerable interindividual differences in academic time use have also been reported by other studies (Kember et al., 1996; Runyan et al., 2013; Schulmeister & Metzger, 2011; Stinebrickner & Stinebrickner, 2004), indicating that some students work quite a lot, whereas others do not. In addition, there is also considerable within-subject variability in academic time use, which shows that students study more during the examination period (Landrum et al., 2006; Ruiz-Gallardo et al., 2011). The differentiation of within- and between-person variance is an important step in understanding psychological processes as they unfold in daily life. The focus on between-person differences allows us to investigate whether students differ in motivation or personality traits, which could, for example, influence study time. It does not answer questions about the within-person processes that vary over time as a function of a given situation. Different situations such as the beginning of semester or the examination period, or simple daily structural patterns, could have a huge impact on behavior or mood and influence time use. Importantly, associations on different levels of analysis can differ. Referring to a famous example, the within-subject association of blood pressure and activity is positive (as walking does increase blood pressure in the moment), whereas the between-subject association is negative (as subjects with lower physical activity usually have higher blood pressure). Accordingly, it is important to separate within and between levels of analyses and to achieve representativeness, especially on the within-subject level, if this is the main level of interest. Separating between- and within-subject variance in the study design and modeling both differences statistically can be achieved using e-diaries as the assessment method and multilevel modeling as the statistical tool.

At the theoretical level, several psychological theories include assumptions about the between-subject mechanisms that influence academic time use. Models of self-regulated learning attempt to explain how students acquire knowledge and skills that encompass cognitive, motivational, and affective strategies. In particular, the concept of self-control has received considerable attention. Self-control is typically defined as “the ability to suppress prepotent responses in the service of a higher goal” (Duckworth & Seligman, 2006, p. 199). Given that self-regulated learning is often oriented toward incentives in the distant future and temptations associated with immediate pleasures (Bembenutty & Karabenick, 2004), students with a greater capacity for self-control should be able to stay on task more effectively. Moreover, findings suggest that students with greater self-control are less prone to motivational conflicts between the domains of study and leisure (Grund & Fries, 2014; Hofer, Kuhnle, Kilian, & Fries, 2012).

Models of self-regulated learning also encompass social support (Fydrich, Sommer, & Brähler, 2007), which may be helpful in terms of informative and emotional support (Aspinwall & Taylor, 1997), structure and reciprocal responsibilities (Slavin, 1996), as well as in the engagement in academic activities (Xerri, Radford, & Shacklock, 2018).

The importance of motivation for successful studying in relation to wellbeing, adjustment to university life, perceived stress (Baker, 2004), course persistence (Vallerand &

Bisonnette, 1992) and academic outcomes (Côte & Levine, 2000) has been well documented in previous studies.

The idea that affect as another component of self-regulated learning plays an important role in the academic learning context has increased over the last years (Linnenbrink-Garcia & Pekrun, 2011; Mega, Ronconi, & de Beni, 2014). Nevertheless, e-diary studies involving university students are rare (Goetz et al., 2014). With regard to the *intra*personal level, recent e-diary studies among university students have shown that studying (compared to other contexts) is typically incompatible with momentary enjoyment, contentment, and positive affect (Goetz, Frenzel, Stoeger, & Hall, 2010; Grund, Schmid, & Fries, 2015). However, whereas positive valence seems to be rare during studying, negative valence has not been addressed in previous studies. In addition, it is not yet known which mood states predict academic time use temporally.

Depending on leisure time characteristics, studies show different associations with well-being. Whereas passive leisure time (e.g., watching TV and computer-related activities done without social interaction) was negatively associated with well-being, active leisure time (e.g., social contact with friends, and physical activity) was positively associated with well-being in a traditional questionnaire study by Holder, Coleman & Sehn (2009). Csikszentmihalyi & Hunter (2003) observed no significant association of passive leisure time, but there was a positive association of active leisure time with happiness in an ESM study. Leisure time in general could be associated with negative reinforcement processes, for example not having to address problems associated with learning or positive reinforcement processes such as the joy of leisure time, whereas study time serves a long-term goal and is perhaps associated with negative short-term consequences. The need for self-regulatory behavior in terms of motivation, self-control and affective states could therefore also have an impact on leisure time, which could be in the opposite direction as for academic time use.

Unfortunately, the associations between time use and psychological variables are complex, as time use is compositional and limited to 24 hours a day (McGregor et al., 2018). In simple terms, not studying enhances the probability of being able to invest in leisure time. Therefore, there is a heightened probability that positive associations of psychological variables with studying coexist with negative associations of the same psychological variables with leisure time, so it is important to analyze both.

In sum, self-control, social support, motivational problems and valence, should explain interindividual differences in academic time use. Unfortunately, few studies that have assessed academic time use have separated within- and between-subject variability and used the experience sampling approach. To improve methodological quality and to generate reasonable estimates of students' time use, we (i) assessed time use hourly using e-diaries to circumvent backfilling and retrospective distortions and (ii) assessed time use for one week at the start of the semester and for an additional week during the examination period to cover fluctuations over the semester.

First, we hypothesized that students' academic time use would match the 40 h/week requirement from the Bologna Process, as accreditation boards in Europe evaluate study courses on matching this criterion and work on achieving this criterion. Second, we assumed that there would be a systematic shift in time use, with active and passive leisure time dominating the start of the semester and more time with learning-oriented activities during the examination period, as previous studies reported increased demands during the examination period (Landrum et al., 2006; Ruiz-Gallardo et al., 2011). Third, based on the finding of heterogeneity in students regarding academic time use (Kember et al., 1996; Runyan et al., 2013; Schulmeister & Metzger, 2011; Stinebrickner & Stinebrickner, 2004), we assumed that meaningful between-subject differences would exist in students' academic time use. Summarizing the abovementioned findings on self-regulated learning, with the importance of self-control, motivation and affective factors, we hypothesized that basic psychological processes such as valence as an affective factor, self-control, social support, and motivation (or a lack thereof) could explain between- and within-subject differences in students' time use. Similarly, we used these psychological processes to explain the variance in active leisure time and passive leisure time, as we assumed the existence of opposite effects compared to academic time use as part of compositional effects and the aforementioned opposing short- vs. long-term differences in reinforcement processes.

3.1.2. Methods

Study Design

To consider within-subject workload differences during the semester, we defined the following two measurement points: one week at the beginning of the semester (*start of the semester;* but not during the first two weeks) and one week during the examination period at the end of the semester (*examination period)*. The latter is in general considered the most stressful period in the German university system, since students' grades for their courses are mainly based on the exams taken during this short period at the end of the semester. This second measurement point started for each individual eight days before an examination and ended the day before the examination. During both weeks, students carried a smartphone (HTC Touch Diamond II©, Windows Mobile 6.5©) with them with a preinstalled e-diary. Personal-level questionnaires were administered at the start of the semester and during the examination period (see below). Data were collected at Authors University in Authors' Country during the winter semester, which generally lasts from the middle of October to the middle of February, with an examination period of several weeks following the conclusion of the lectures in February.

Students from particular courses were asked to participate, which were selected for practical reasons (such as courses that primarily were attended by students in their first and third semesters). In groups of approximately 20, the students were informed about the study, asked to complete the first set of individual-level questionnaires, and started the e-diary. After the study week, the students returned the devices and completed another set of personal-level questionnaires, which was different from the first set. The set was divided in two to balance participant burden, because there was no reason to believe that any differences in assessment time would affect the reported data. Later in the semester, the students informed the research team about their examination dates. On that basis, appointments for the second measurement were made individually exactly one week before an examination. The e-diary assessment ended the evening before the examination. After the examination, the devices were returned. Again, personal-level questionnaires were completed before and after the second assessment week. The devices, e-diary questions, procedure and timetable were the same in the examination period, except a few of the trait questionnaires that differed. To ensure compliance, the students received an individual report of their results with a personal coaching session on how to address their stressors. All students provided written informed consent. Ethical approval was not required for this study in accordance with the national and institutional guidelines.

Subjects and Data

One hundred fifty-four students gave their informed consent. Most of the participants were male (79%) and studying industrial engineering and management (85%). The mean age of all participants was 21.1 years (*SD* = 1.5). Most of the students were in their first (25%) or third semester (51%), and 99% of the participants were German in terms of nationality. Forty-three percent of them had a part-time job. They worked a mean of 9.2 h/week (*SD* = 7.4) during the lecture period and 15.8 h/week (*SD* = 12.9) during the semester break, which includes the examination period. Due to technical problems, smartphone data from two students were lost at the start of the semester. Additionally, three smartphone datasets were lost during the examination period. Five participants dropped out before the second measurement, resulting in a final e-diary sample of 152 at the start of the semester and 146 in the examination period.

Measurements: Momentary Data

To promote consistency throughout the paper, data from the e-diary will be labeled momentary data, whereas data from the questionnaires and the personal-level aggregated momentary data will be called personal-level data. For the statistical analysis, we refer to momentary data as within-subject data and personal-level data as between-subject data.

The e-diary emitted a signal every full hour (e.g., 9:00 a.m., 10:00 a.m., 11:00 a.m.) during the waking hours of each day during both assessment weeks. We chose such a nonrandom sampling scheme to improve the accuracy of the time use estimates. We assumed that it would be easier to report time use from full hour to full hour (e.g., from 9:00 a.m. to 10:00 a.m.), rather than for two random assessment points (e.g., 9:27 a.m. to 10:48 a.m.). We allowed for a ten-minute maximum response delay. If the student did not answer within this time frame, the data were recorded as missing. Students put the e-diary in sleep mode before going to bed and started it again in the morning. The e-diary software MyExperience Movisens Edition (Movisens GmbH, Karlsruhe, Germany; Froehlich, Chen, Consolvo, Harrison, & Landay, 2007) time-stamped all responses automatically over the entire week.

Time use: We used the following ten different categories to classify time use: courses (e.g., lectures, workshops, tutorials), learning-oriented activities (e.g., reading relevant literature, thesis work, presentation preparation, literature research, explaining things to other students), other academic activities (e.g., borrowing books from the library, printing documents, organizing things at the study office), transport and idle time, household, eating and body care, job, active leisure time (e.g., sport, social contacts), passive leisure time (e.g., watching television, playing on the computer), sleeping and other activities. This allowed the students to split up the 60 (plus 10) minutes of their actual time use into the ten categories. For example, a possible result would be 34 minutes of learning-oriented activities, 10 minutes of body care, 12 minutes of transport, and 7 minutes of idle time.

Valence: To assess momentary mood, we used the momentary Multidimensional Mood Questionnaire (Wilhelm & Schoebi, 2007), which has shown good sensitivity to change, good weekly reliability estimates, and good within-subject reliability estimates of *r(weekly valence)* = .92 and *r(within valence)* = .70. The within-subject predictors momentary valence and valence change and the between-subject predictor weekly valence were generated from that scale (for details, see data analysis section).

Measurements: Personal-Level Questionnaires

Self-control: We assessed self-control via the German version of the Self-Control Schedule (SCS-D; Jacobi, Brand-Jacobi, Westenhöfer, & Weddige-Diedrichs, 1986), which covers the following four underlying constructs: ability to work in spite of delayed gratification, self-control of negative emotions and pain, utilization of techniques and self-verbalization regarding self-control, and belief in the controllability of one's own life. We used the summed index of the entire scale, ranging from -93 to +93, with positive values indicating more self-control capacity. The SCS-D has good psychometric properties, with a Cronbach's alpha of .82, split-half coefficient of .72, and test-retest reliability of .73 (Jacobi et al., 1986). In our study, comparable to the aforementioned results, Cronbach's alpha was .80.

Social support: We used the Social Support Questionnaire (FsozU; Fydrich, Sommer, & Brähler, 2007) to measure perceived social support. A total score was calculated by computing the mean of the scores of the three subscales (affective support, practical support, and social integration). Ranging from one to five, higher values indicated greater social support. The FsozU has good psychometric properties, with Cronbach's alpha values ranging from .81 to .93, a split-half coefficient ranging from .79 to .90, and satisfactory factorial and construct validity (Fydrich et al., 2007). Again, the Cronbach's alpha of .93 of our study was comparable with the results mentioned above.

Motivational problems: To assess a wide range of parameters that might be relevant to students' time use, we used the student survey developed by Thiel, Veit, Blüthmann, Lepa, and Viczko (2008). This survey was specifically designed for student time use studies and covers a wide range of relevant parameters such as motivational problems, study difficulties relating to preparation for examinations, or lack of comprehension of the study subject. For hypothesis 3, we used the following two items that addressed motivational problems in students: "I have problems motivating myself to learn" and "During learning, I often get distracted by other things". We calculated the mean of the two items on a scale from one to eight, with higher values indicating more motivational problems (Cronbach's alpha = 0.82).

Missing Data and Imputation

Missing data are unavoidable in e-diaries, as completing an entry while driving a car, swimming or showering, for example, is not possible. In addition, prompting signals may not be heard in noisy environments. Additionally, e-diary software can have technical problems, or participants can be unwilling to complete the e-diary on time (e.g., during visiting lectures or while at the opera). Fortunately, standard analyses of e-diary data such as multilevel regression models automatically handle missing data. However, this is only the case if the analyses focus on within-subject effects, which is the standard case in e-diary research such as the prediction of momentary mood by stressors or time. Unfortunately, these models are unhelpful in terms of our first hypothesis as we were interested in the cumulative value (the sum instead of the mean) of academic time use over the whole week to compare it to the standard of 40 h/week. Therefore, an additional imputation procedure was necessary to obtain ratings for every waking hour to achieve an estimation of total academic time use over the week.

To take into account both within- and between-subject sources of variance, we used the following linear equation model to estimate the missing data (see Priebe et al., 2013):

$Y_{ij} = Y_{i.} + Y_{.j} – Y_{..}$, where

Y_{ij} = the estimated value of a category (Y) of a person (i) at a given timeslot (j),

$Y_{i.}$ = the person's mean score for this category over all timeslots,

$Y_{.j}$ = the mean of a timeslot for a given category over all persons,

$Y_{..}$ = the grand mean for this category over all timeslots and persons.

In some rare cases, the estimation resulted in negative values. They were negligible in number and were set to zero. In addition, if participants forgot to activate the sleep mode at night, we set the sleeping time to a maximum of ten hours and defined the remaining hours as missing data.

If the time between the previous diary entry (e.g., 9:03 a.m.) and the next entry (e.g., 10:00 a.m.) was under 60 minutes and caused, for example, by the delayed response of the participant in the last diary entry (e.g., 9:03 a.m.) or technical problems, we increased all the ratings proportionally to full hours. For the compliance calculation, we used a conservative approach and added these "increased" ratings to the missing data. The overall compliance (calculated as the number of missing data entries divided by completely filled data entries with a 60-minute time frame) was very good at the start of the semester (80%) and at the examination period (89%). We used the imputed data only to test our first and second hypotheses but not for the multilevel model that was developed to test the third hypothesis, as relationships and not sums were the main focus.

Data Analyses

To calculate academic time use to test hypothesis 1, we used the following two different approaches: we first calculated academic time use by summing the time used for learning-oriented activities, course attendance, and other academic activities. Academic time use in the

ECTS Bologna System is defined as the estimated time that a student typically uses for learning activities, such as attending classes, projects, practical work, or independent study to reach defined learning goals (ECTS users guide, 2015). As Kember (2004) noted, the utility of a measure for course workload adding independent study is questionable as the definition of learning activities, as independent study is rather notional. In a second calculation, we included additionally half of the "transport and idle time". We added this category, which reflects, among other things, the time required to walk from one course to another and waiting until the course starts, as these activities prevent time from being used for other activities and therefore are clearly related to studying. We used a one-sample t-test to compare the assessed academic time use with the 40 h/week Bologna criterion.

To compare the e-diary time use data from the start of the semester to that of the examination period, to test our second hypothesis, we used paired t-tests. If the assumption of normality was violated, we used the Wilcoxon test. We used visual inspection and the Kolmogorov-Smirnov test with Lilliefors-correction and a small alpha of 0.1% because of the robustness of the t-test against the violation of normality (e.g., Bortz, 1989). Effect size estimates were calculated using G*Power© 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007).

To investigate which psychological processes were related to student academic time use, our third hypothesis, we chose a more conservative approach to estimate hourly workload. We simply summed the time used with learning-oriented activities and attending courses over the previous 60 minutes without including the two categories of other academic activities and transport and idle time. We did this because we assumed that the time use scores of learning-oriented activities and attending courses would be more homogenous in content than the combined score of all four categories. Due to the nested data structure, we used a multilevel regression model with a three-level structure. Occasions (level 1) were nested within days (level 2), which were nested within individuals (level 3). At the beginning of the semester, the maximum data points used were 17,107 at level 1, 1,106 at level 2 and 146 at level 3. In the examination period, the maximum data points used were 17,374 at level 1, 1,052 at level 2 and 145 at level 3. One advantage of such a multilevel model is that a different quantity of data points per person can be handled and, thus, used in the analysis. To make a clear and interpretable separation of the within- and between-subject effects, we centered our variables and included (mean individual) valence as an additional personal-level variable at the between-subject level (see Nezlek, 2012) so that it described the weekly individual averages of the valence ratings assessed by the e-diary. Momentary valence was centered on the person's mean (group-mean centering). Grand-mean centering was used for the between-subject predictors. To control for time trends, we included time as hours of the day in the model. To control for time effects that were not only linear, we also included quadratic hours as a variable in the model.

Weekend effects were controlled for using a dummy coded variable, with "weekend" coded as one and "working day" coded as zero. The control variable "hours of the day" was centered on 12 o'clock noon. We calculated six multilevel models as follows: 1) learning-oriented activities and courses at the start of the semester, 2) active leisure time at the start of the semester, 3) passive leisure time at the start of the semester 4) learning-oriented activities and courses during the examination period, 5) active leisure time during the examination period, and 6) passive leisure time during the examination period. Even though these are different models, their outcomes are not totally independent. For example, if during a given hour, 60 minutes were spent on learning-oriented activities, then active and passive leisure time had to be zero. However, learning-oriented activities, courses, active and passive leisure time did not always add up to 60 minutes, as there were other possibilities such as housework, eating, body care, other academic activities, transport and idle time, and time invested in a part-time job. We included as level-three variables the personal-level variables of social support, self-control, and motivational problems. Full maximum likelihood estimation was used for all six multilevel models. All fixed effects from level 1 and level 2 were allowed to vary randomly.

Data management, especially the imputation procedure, was done using SAS© 9.3 (SAS Institute Inc., Cary, NC, USA). Statistical analyses for the first and second analyses were performed using SPSS© 21 (SPSS Inc., Chicago, Illinois). For the multilevel models used to test the third hypothesis, we used HLM© 7 (Raudenbush & Bryk, 2002). An alpha level of 5% (two-sided) was used for all statistical analyses.

3.1.3. Results

Time Use

Figure 1 shows the time use data for both measurement points: the start of the semester and the examination period. Summing “courses”, “learning-oriented activities”, and “other academic activities” into an academic time use score for each measurement point resulted in values above and below the 40 h/week (M_{m1} = 31.6, SD_{m1} = 11.9; M_{m2} = 49.8, SD_{m2} = 20.4). Averaging both measurement points revealed a mean academic time use of 40.24 h (SD_{m1m2} = 13.2), which is not significantly different from the Bologna criterion, $t(153)$ = 0.22, p = .824, d = 0.02 (hypothesis 1). However, when we added 50% of the transport and idle time to the academic time use calculation, academic time use was slightly above the criterion ($M_{m1m2transport}$ = 43.7, $SD_{m1m2transport}$ = 13.3, $t(153)$ = 3.44, p = .001, d = 0.28). In addition, academic time use during the examination period was significantly higher, $t(143)$ = -10.48, p < .001, than it was at the start of the semester, yielding a large effect (d = -0.87).

As predicted in our second hypothesis, Figure 1 graphically reveals a systematic shift in time use from the start of the semester to the examination period. Specifically, at the start of the semester, students spent more time engaged in courses, t(143) = 20.26, p < .001, d = 1.69, other academic activities, z = -2.56, p = .010, d = 0.22 ($Median_{m1}$ = 1.73; IQR_{m1} = 2.43; $Median_{m2}$ = 1.22; IQR_{m2} = 2.09), transport and idle time, t(143) = 7.38, p < .001, d = 0.61 and passive leisure activities, $t(143) = 5.72$, $p < .001$, $d = 0.48$, compared to the examination period. During the examination period, they spent more time engaged in learning-oriented activities, $t(143) = -18.77$, $p < .001$, $d = -1.56$, housework, eating, and body care, $t(143) = -2.09$, $p = .038$, $d = -0.17$ and active leisure activities, $t(143) = -4.15$, $p < .001$, $d = -0.35$, compared to the start of the semester. In the job category, no significant changes between the two measurement points were found, $z = -0.40$, $p = .693$, $d = 0.25$ ($Median_{m1} = 0.08$; $IQR_{m1} = 3.19$; $Median_{m2} = 0.11$; $IQR_{m2} = 2.44$). In addition, Figure 1 provides insight into the huge between-subject differences. For example, the mean time used with learning-oriented activities at measurement point two had a standard deviation of 20.4 h.

To examine between-subject differences more closely (hypothesis 3), we summed the time use scores for the learning-oriented activities and courses categories to form an academic time use score and plotted its distribution for both assessment points (see Figure 2). The range of workload for the start of the semester was already quite impressive. Specifically, students' scores ranged from the first category "0–10 h/week" to the last category of "51–60 h/week". The range during the examination period was nearly twice that of the start of the semester ("0–10 h/week" to "91–100 h/week").

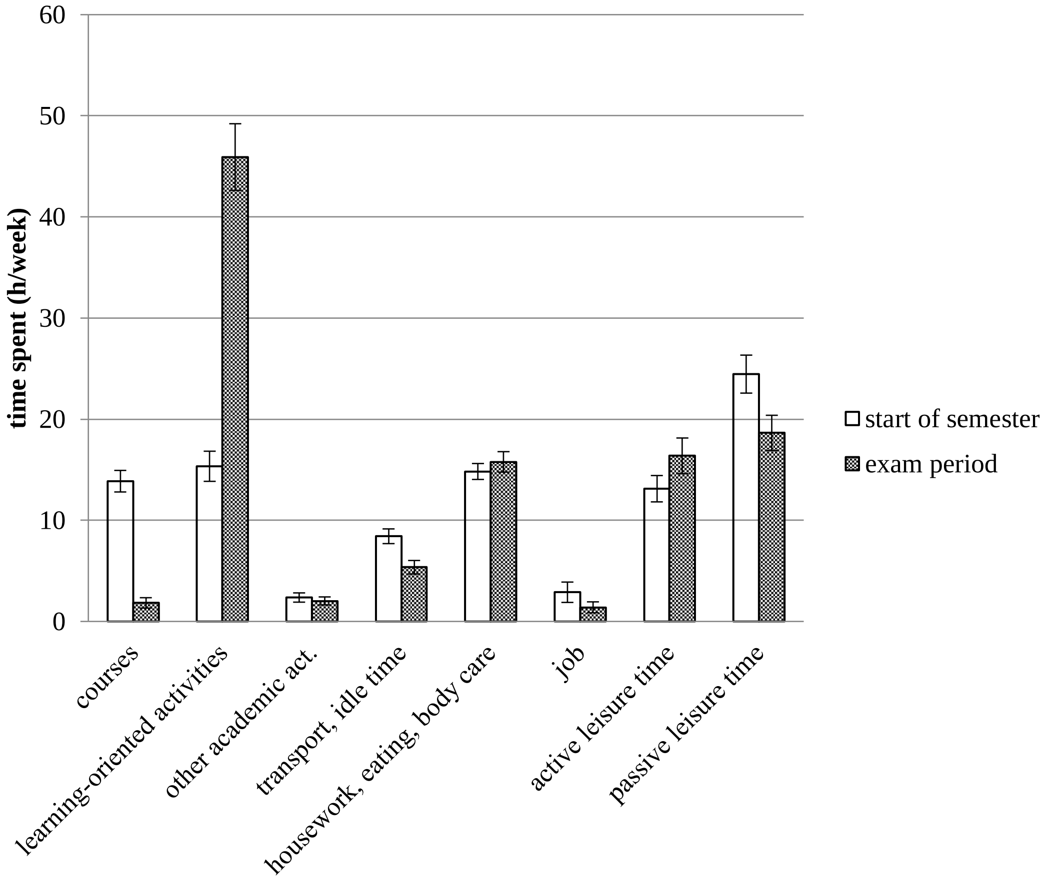
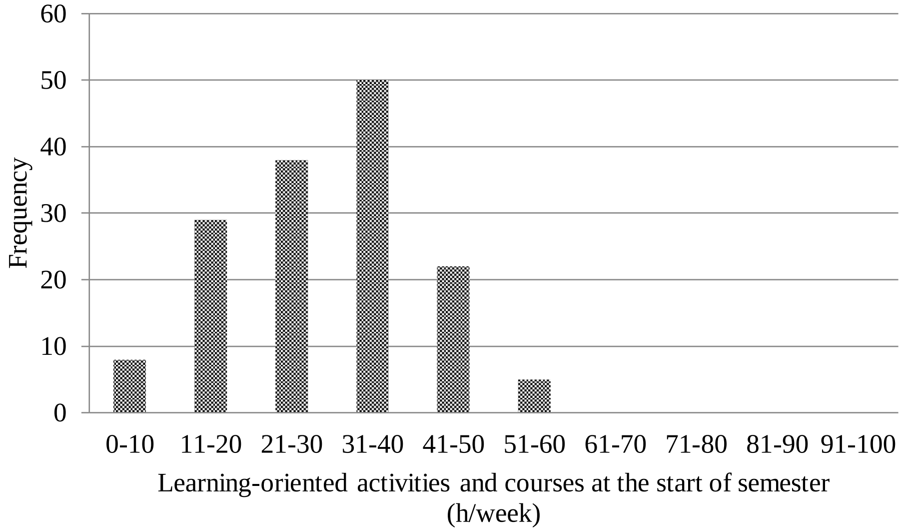


Figure 1. Average for each time use category from the e-diary assessment at start of semester and in the examination period (N = 144). The height of the bar denotes the mean and the whiskers mark the 95% confidence interval for the mean of the categories.



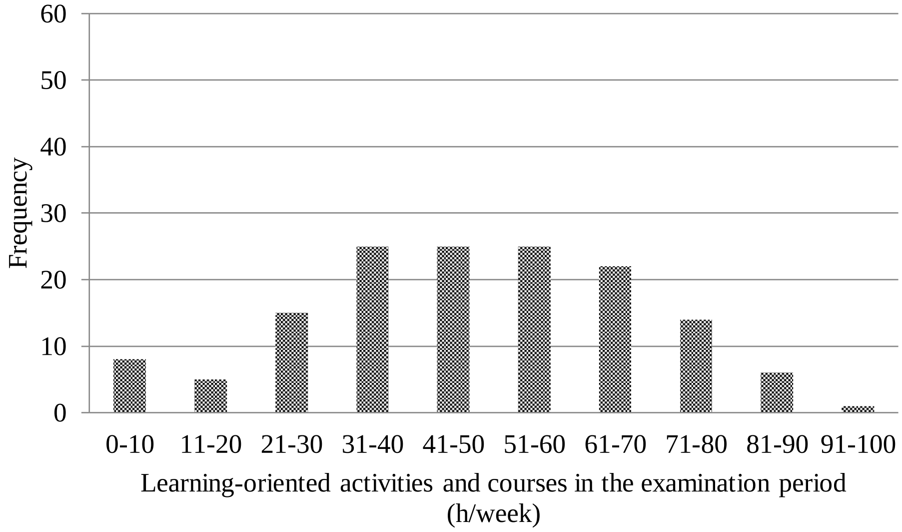


Figure 2. Distribution of the student's time used for learning-oriented activities and courses (academic time use) in h/week at the start of the semester and in the examination period (N = 144).

There are sizable differences in time spent studying per week among students. Frequency denotes number of students in each bin.

Predicting students' time use

To explain between- and within-subject differences in students' time use (hypothesis 3), we included basic psychological processes as predictor variables in six different multilevel models (models I-III: start of the semester; models IV-VI: examination period). We first calculated six null models to determine the two intraclass correlation coefficients (ICC2 = ICC day level; ICC3 = ICC person level) of each model at the beginning of semester (ICC2(model I) = 0.13; ICC3(model I) = 0.06; ICC2(model II) = 0.09; ICC3(model II) = 0.07; ICC2(model III) = 0.13; ICC3(model III) = 0.07) and in the examination period (ICC2(model IV) = 0.07; ICC3(model IV) = 0.11; ICC2(model V) = 0.05; ICC3(model V) = 0.07; ICC2(model VI) = 0.06; ICC3(model VI) = 0.07). As within-subject predictors, we included valence (t_{-1}), valence (t_{-1}–t_0), hours, hours^2 and the dummy coded variable of weekend. Valence (t_{-1}) describes momentary valence before the predicted time use (which is the actual time use from t_{-1}–t_0). In contrast, valence (t_{-1}–t_0) describes the change in valence during the time use of a student (for example, how mood deteriorates during learning-oriented activities). In addition, we included social support (M = 4.1, SD = 0.5), self-control (M = 11.3, SD = 19.2), motivational problems (M = 5.4, SD = 1.7), and weekly valence (M_{m1} = 4.5, SD_{m1} = 0.8; M_{m2} = 4.2, SD_{m2} = 0.9) as between-subject predictors.

Table 1. Results from the Multilevel Analyses

	Start of Semester						Exam Period					
	Model I		Model II		Model III		Model IV		Model V		Model VI	
	Learning & courses[a]		Active leisure time[a]		Passive leisure time[a]		Learning & courses[a]		Active leisure time[a]		Passive leisure time[a]	
Predictors	β(SE)	t	β(SE)	t	β(SE)	t	β(SE)	t	β(SE)	t	β(SE)	t
Between												
Intercept	23.66(0.66)**	35.93	3.04(0.32)**	9.38	4.54(0.33)**	13.68	29.62(0.98)**	30.10	3.37(0.44)**	7.71	5.07(0.37)**	13.63
Social support	0.66(0.88)	0.75	-0.83(0.67)	-1.23	0.53(0.72)	0.74	3.73(1.40)**	2.66	1.49(0.87)	-1.72	-1.10(0.69)	-1.59
Self-control	-0.01(0.02)	-0.35	-0.03(0.02)	-1.79	0.01(0.02)	0.68	0.04(0.04)	1.07	-0.03(0.02)	-1.42	0.00(0.02)	0.05
Motivation[d]	-1.31(0.28)**	-4.68	0.42(0.16)**	2.65	0.65(0.19)**	3.47	-1.53(0.48)**	-3.22	0.46(0.22)*	2.04	0.45(0.19)*	2.38
(weekly) Valence	-2.15(0.59)**	-3.68	0.84(0.45)	1.87	0.72(0.38)	1.89	-1.89(0.84)*	-2.26	0.93(0.56)	1.65	0.48(0.37)	1.32
Within												
Valence (t_{-1})	-3.29(0.41)**	-8.04	0.82(0.26)**	3.21	3.35(0.27)**	12.55	-4.00(0.41)**	-9.81	0.79(0.26)**	3.10	2.54(0.25)**	10.06
Valence (t_{-1}–t_0)[b]	3.10(0.29)**	10.89	-0.45(0.18)*	-2.50	-2.23(0.21)**	-10.73	2.87(0.29)**	9.85	-0.13(0.17)	-0.77	-1.54(0.18)**	-8.75
Within (control)												
Hours	0.37(0.05)**	7.55	0.07(0.05)	1.49	0.23(0.06)**	3.74	1.37(0.11)**	12.84	0.16(0.05)**	3.09	0.50(0.06)**	8.39
$Hours^2$	-0.16(0.01)**	-19.58	0.09(0.01)**	10.35	0.13(0.01)**	13.61	-0.29(0.02)**	-13.65	0.13(0.01)**	12.33	0.05(0.01)**	4.28
Weekend[c]	-8.13(0.60)**	-13.65	3.44(0.54)**	6.38	8.85(0.67)**	13.17	-1.93(0.80)*	-2.41	0.41(0.43)	0.96	1.79(0.50)**	3.60

*$p < .05$; **$p < .001$; [a]learning-oriented activities and courses, active and passive leisure time: time use data from t_{-1}–t_0 in min/h; [b]valence (t_{-1}–t_0): Difference score of valence before minus after time use; [c]weekend was dummy-coded with working day coded as zero and weekend coded as one; [d]motivational problems

Time use at the start of the semester (models I-III)

We calculated three different multilevel models to predict time spent on learning-oriented activities and courses (model I), active leisure time (model II), and passive leisure time (model III) at the start of the semester. To improve clarity, in the following section, we report the results simultaneously for all three models for each predictor, rather than for one model after another.

Momentary valence (t_{-1}) did significantly predict subsequent time use (which is the actual time use from t_{-1}–t_0) in all three models (I, II, III). The association with time spent studying was negative ($p_{m1} < .001$), whereas it was positive for active leisure time ($p_{m1} = .002$) and passive leisure time ($p_{m1} < .001$). This indicates that the worse the students felt, the more time they spent studying and the less time they spent engaging in active and passive leisure activities in the following hour. The negative association with studying may be interpreted as a feeling of “bad conscience”.

Changes in valence (t_{-1}–t_0) were also significantly associated with time use. More specifically, there was a significant positive effect on time spent on learning-oriented activities and in courses ($p_{m1} < .001$), whereas there was a negative effect on time spent on active ($p_{m1} = .014$) and passive leisure activities ($p_{m1} < .001$). This indicates that the more the students’ valence decreased, the more time they spent studying, and the more the students’ valence increased, the more time they spent in active and passive leisure time during the hourly assessments.

Several psychological processes that were included in our multilevel model as between-subject predictors also revealed significance. Motivational problems had a significant negative effect on time spent studying ($p_{m1} < .001$) and a significant positive effect on time spent on active ($p_{m1} = .009$) and passive leisure activities ($p_{m1} < .001$). The more motivational problems that students generally reported with regard to studying, the more time they spent on active and passive leisure activities and the less time they spent studying. Weekly valence, as a between-subject predictor, had a significant negative association with time spent studying ($p_{m1} < .001$), which indicates that generally feeling bad was associated with more time spent studying. The associations between weekly valence with active and passive leisure activities were not significant. Somewhat unexpectedly, self-control and perceived social support did not have any significant effect at the start of the semester.

In addition, the weekend versus weekday differentiation did have a significant effect on all three outcomes (all $p_{m1}s < .001$). Students studied less, attended fewer courses, and invested more time in passive and active leisure activities on the weekends compared to weekdays. Time, modeled as hours of the day, had a positive and significant linear effect on time spent studying ($p_{m1} < .001$) and time spent on passive leisure activities ($p_{m1} < .001$). Nonlinear effects, modeled as squared hours of the day, had a significant negative effect on time spent studying and a significant positive effect on active and passive leisure activities (all $p_{m1}s < .001$). Taking the quadratic and the linear effect of hours of the day together, these findings indicate (when looking at an assumed waking time from 8.00 a.m. to 11.00 p.m.) that: a) the later it was in the morning, the more time students spent studying, with a peak before midday. After that, time spent studying declined until evening; and b) active and passive leisure time were increasing over the day with very low values until noon.

To sum up, momentary valence (t_{-1}) and changes in valence (t_{-1}–t_0) were significantly associated with time use. The worse students felt and the more the students' valence decreased, the more time they spent studying, and the less time they spent in active and passive leisure time during the following hour. The more motivational problems, the more time they spent on active and passive leisure activities and the less time they spent studying. The significant between-subject predictor weekly valence revealed that generally feeling bad was associated with more time spent studying.

Time use during the examination period (models IV-VI)

Momentary valence (t_{-1}) and changes in valence (t_{-1}–t_0) significantly predicted subsequent time use (time use from t_{-1}–t_0) in all three models (model IV: learning-oriented activities and courses; model V: active leisure time; model VI: passive leisure time). Similar to the findings at the start of the semester, valence had a negative effect on time spent studying ($p_{m2} < .001$), whereas the effect on active ($p_{m2} = .002$) and passive leisure time ($p_{m2} < .001$) was positive. Similarly, changes in valence (t_{-1}–t_0) had a significant positive association with time spent studying ($p_{m2} < .001$) and a significant negative association with passive leisure activities ($p_{m2} < .001$).

Again, among all between-subject predictors, motivational problems significantly influenced time spent studying ($p_{m2} = .002$) and active ($p_{m2} = .043$) and passive leisure time ($p_{m2} = .018$) in the same direction as at the start of semester. Again, weekly valence as a between-subject factor had a significant negative association with time spent studying ($p_{m2} = .026$) but no effect on active and passive leisure time. Contrary to the start of the semester, social support had a significant positive effect on time spent studying ($p_{m2} = .009$), indicating that the more social support that students' perceived, the more time they spent studying hourly during the week. Once again, self-control did not show significant between-subject effects.

Controlling for time variables, the weekend effect was significant for time spent studying ($p_{m2} = .017$) and passive leisure time ($p_{m2} < .001$). Students studied more on weekdays and engaged in more passive leisure activities on the weekend compared to weekdays. Time, modeled as hours and squared hours of the day, had a significant association with all three outcomes (hours: time spent studying and passive leisure time: $p_{m2} < .001$; active leisure time: $p_{m2} = .002$; hours² all $p_{m2}s < .001$). Taking the quadratic and linear effect of hours of the day together, these findings indicate (when looking at an assumed waking time from 8.00 a.m. to 11.00 p.m.) that: a) the later it was in the morning, the more time students spent studying, with a peak before midday. After that, time spent studying declined until evening; and b) active and passive leisure time were increasing over the day with very low values until noon.

To sum up, all findings from the beginning of the semester were replicated except the effect of perceived social support. There was a significant effect of social support, meaning, the more social support, the more time they spent studying hourly during the week.

3.1.4. Discussion

As hypothesized, on average, the academic time use of students did not differ from the Bologna criterion of 40 h/week. Even if we considered 50% of transport and idle time, the numbers were only slightly above the target value of 40 h/week. This result is in contrast to the findings of other studies that showed lower academic time use (Kolari, Savander-Ranne, & Viskari, 2007; Kozar, Marcketti, & Gregoire, 2006; Nonis et al., 2006). However, the finding is in accordance with the studies by Kember et al. (1996) and Marshall (2018), which showed that the given target value was accomplished by students. However, the generalizability of academic time use studies is generally limited by the sample. Our sample primarily consisted of male students who were studying industrial engineering and management at one university. Therefore, the results of other studies that assessed, for example, students of sociology, might differ because of the diverse fields of study. In addition, investigating the same field of study at a different university could have led to different results as well. Compared to cross-sectional research, where the major goal is to achieve a representative sample of participants, in intensive longitudinal research the primary goal is to achieve a representative sample of situations (even though achieving a representative sample of individuals is also of importance). As we used a "coverage" sampling strategy (hourly assessments during daytime querying about last hour for a whole week) and because we had good compliance, we are confident that we achieved a representative sample of situations within subjects. Even though general conclusions are limited, we want to highlight that we used a methodological approach with real-time assessment, thereby preventing backfilling and probably associated recall bias, which is especially important when the phenomena of interest fluctuate over time. Other investigations used paper-pencil diaries, so that the differing results could also be due to the different assessment strategies used, with paper-pencil diaries being prone to backfilling and recall biases. In addition, it may be speculated that the Bologna reform, with accreditation bodies' reviewing how the 40 h are broken down for each course, may have streamlined academic time use across disciplines and universities.

The hypothesized systematic shift in the reported time use from the start of the semester to the examination period was clearly evident in our data. Across the semester, learning-oriented activities increased by nearly 20 h/week, whereas passive leisure time decreased. Surprisingly, active leisure time was higher during the examination period. Additionally, passive leisure time was still high during this period, with a mean of 18.6 h/week. Between-subject differences were huge. Almost one-quarter of the sample had an estimated academic time use for the whole semester of more than 50 h/week (using the mean of both measurement points as proxy for the whole semester). In addition, almost one-quarter of the students studied for fewer than 30 h/week. In the examination period, between-subject differences were even more pronounced.

The substantial within- and between-subject differences in academic workload allowed us to test the psychological processes that might explain these differences. Our multilevel models revealed three main findings. First, both measurement points (the start of the semester and examination period) provided highly comparable effects in association with the predictors, which increased our confidence in the findings.

Second, valence before time use was negatively associated with academic time use and positively associated with leisure time consistently across all six models. In other words, students were in a good mood before leisure time and a bad mood before learning-oriented activities. Given these findings, it seems appropriate to assume that students look forward to leisure time but approach studying uneasily. Another plausible explanation for students' being in a bad mood before studying might be that they had studied before already. To control for that possibility statistically, we ran additional multilevel models, controlling for time use the hour before, which did not change the association between valence and studying. Moreover, valence diminished during learning-oriented activities, whereas valence improved during leisure time. Generally, these findings are in accordance with those of Goetz et al. (2010), which showed a negative association between studying and enjoyment at the momentary level. Not surprisingly, taking these findings into account, weekly valence was also negatively related to academic time use, indicating that those students who studied a lot felt worse over the course of the week. We found a smaller association of active leisure time than that of passive leisure time with valence and valence changes, indicating that more passive leisure time was associated with more positive valence and higher increases in valence than active leisure time. This finding is consistent with the idea of a differentiation between active and passive leisure time. However, the direction of the associations is contrary to the literature on passive and active leisure time and well-being (Holder, Coleman & Sehn, 2009; Csikzentmihalyi & Hunter, 2003). Differences in the assessment strategy (Holder, Coleman & Sehn, 2009) or in the analyzing procedure (aggregated within subject correlations without control variables in Csikzentmihalyi & Hunter, 2003) could explain the inconsistent findings. However, more research is needed under which circumstances and for which people passive leisure time has an advantage over active leisure time on affective states.

Third, at the between-subject level, we investigated the contribution of motivational problems, self-control, and social support. Motivational problems showed a coherent pattern across all models. Specifically, fewer motivational problems were associated with more time spent on learning-oriented activities and courses. Motivation seems to be an important psychological process that drives academic time use. Brahm, Jenert, & Wagner (2017) found a gradual decline in student motivation throughout the first academic year. This decline was less pronounced if the students did enjoy learning. They conclude that it is important to consider and try to keep enjoyment as a crucial part in student learning. Marshall (2018) found a significant correlation of r = 0.4 between time spent studying and motivation.

Social support was only related to academic time use during the examination period. Perhaps social support helps in the exchange of information about the study subject. It might also be that students test their level of acquired knowledge in learning groups. It might also be that social support is needed more in the form of emotional support to relieve the high level of stress in this period, which leads to more studying.

Somewhat surprisingly, self-control as a cognitive factor did not have any significant between subject associations. Given the impressive literature demonstrating the positive relationship between self-control and academic functioning (see Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012 for a recent overview), a positive effect of self-control on academic time use was expected. Restricted variance is not a plausible potential explanation, given that self-control showed meaningful variance. However, we observed a substantial correlation between self-control and motivational problems (r = -.24, p = .004), indicating that students who reported fewer motivational problems also reported higher self-control. This finding is in line with the idea that motivation is a powerful predictor of academic persistence, leaving little between-person variance to be explained by more volitional concepts such as self-control (Inzlicht & Schmeichel, 2012). That is, if there is enough motivation, there is no additional need for a certain capacity of self-control. In contrast, if there is no motivation at all, then self-control alone does not appear to be of great importance to persistence in studying.

3.1.5. Limitations

Even though we used a cutting-edge methodological assessment strategy that included real-time assessment with electronic devices that prevented backfilling and repeated assessment that enabled us to separate within- and between-variance components, we want to address some of the limitations of the current study. First, to ensure high compliance and low reactivity in e-diary studies, a fair balance between the number of assessment points and number of items is necessary to reduce participant burden. Given the hourly measurement points (up to 200 per individual) and the additional blood pressure and cortisol measurements (which were not reported), we had to manage participant burden by restricting the number of items and measurement weeks. Even though it would be tempting to have multiple questionnaires for each construct, we chose the student survey developed by Thiel et al. (2008) to estimate multiple relevant constructs with just one questionnaire. Similarly, we were not able to assess hourly workload during the entire 14-week semester. Fortunately, our analyses revealed meaningful associations and differences within and across constructs and, at the same time, an impressively high compliance of 80% and 89% in the two different assessment weeks.

Second, we were not able to provide empirical evidence regarding the association between workload and grades, as we could not assess the latter due to data protection and privacy issues. However, investigations of the association between academic time use and grades have generated mixed results (Dickinson & O'Connell, 2001; George, Dixon, Stansal, Gelb, & Pheri, 2008; Plant, Ericsson, Hill, & Asberg, 2005). In addition, the frequently found weak associations might be attributed to biased estimates of academic time use caused by backfilling in paper diaries. Third, our students were mostly male and mainly studying industrial engineering and management, which limits the generalizability of our findings.

3.1.6. Conclusion

In our sample of students in engineering sciences, the students' average academic time use seemed to conform to the specifications and guidelines administered by the Bologna reform. Our design enabled us to reveal large between- and within-subject differences in students' academic time use and explain these differences with psychological processes. Valence appeared to be a strong predictor of time use, highlighting the important role of affective factors in self-regulation and motivational processes of academic time use. Future research is needed to investigate the role of the consequences of negative valence on learning processes in daily life. Studies should detangle affective states that accompany the motivational, self-regulatory components of study time and the learning process. They also should investigate what emotion regulatory strategies in which context in daily life help students address mistakes in a successful manner so that positive valence can be reestablished and learning goals can be met. This could be helpful for professionals in designing appropriate interventions regarding emotion regulation in the learning process. Future studies should also enhance the understanding of within and between person variables and processes that influence academic time use further, especially regarding individual differences in within-subject relations, which may be a next step in helping to discover problematic trajectories and facilitate specific interventions.

3.1.7. References

Aspinwall, L. G., & Taylor, S. E. (1997). A stitch in time: Self-regulation and proactive coping. *Psychological Bulletin, 121*(3), 417–436.

Baker, S. R. (2004). Intrinsic, extrinsic, and amotivational orientations: Their role in university adjustment, stress, well-being, and subsequent academic performance. *Current Psychology*, *23*(3), 189–202.

Bembenutty, H., & Karabenick, S. A. (2004). Inherent association between academic delay of gratification, future time perspective, and self-regulated learning. *Educational Psychology Review*, *16*(1), 35–57.

Bortz, J. (1989). *Statistik für Sozialwissenschaftler* (3rd ed.). Berlin, Germany: Springer.

Brahm, T., Jenert, T., & Wagner, D. (2017). The crucial first year: a longitudinal study of students' motivational development at a Swiss Business School. *Higher Education, 73*(3), 459-478.

Côte, J. E., & Levine, C. G. (2000). Attitude versus aptitude: Is intelligence or motivation more important for positive higher-educational outcomes? *Journal of Adolescent Research*, *15*(1), 58–80.

Csikszentmihalyi, M., & Larson, R. (1987). Validity and reliability of the Experience-Sampling Method. *The Journal of Nervous and Mental Disease, 175*(9), 526–536.

Csikszentmihalyi, M., & Hunter, J. (2003). Happiness in everyday life: The uses of Experience Sampling. *Journal of Happiness Studies, 4*, 185–199,

Dickinson, D. J., & O'Connell, D. Q. (2001). Effect of quality and quantity of study on student grades. *The Journal of Educational Research*, *83*(4), 227–231.

Duckworth, A. L., & Seligman, M. E. P. (2006). Self-discipline gives girls the edge: Gender in self-discipline, grades, and achievement test scores. *Journal of Educational Psychology*, *98*(1), 198–208.

ECTS users guide (2015), retrieved April 4, 2019 from http://ec.europa.eu/education/ects/users-guide/docs/ects-users-guide_de.pdf.

Fahrenberg, J., Myrtek, M., Pawlik, K., & Perrez, M. (2007). Ambulatory Assessment - Monitoring behavior in daily life settings. *European Journal of Psychological Assessment*, *23*(4), 206–213.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191.

Froehlich, J., Chen, M. Y., Consolvo, S., Harrison, B., & Landay, J. A. (2007). MyExperience: A system for *in situ* tracing and capturing of user feedback on mobile phones. In *Proceedings of the 5th international conference on Mobile systems, applications and services* (pp. 57–70). San Juan, Puerto Rico: ACM.

Fydrich, T., Sommer, G., & Brähler, E. (2007). *Fragebogen zur sozialen Unterstützung: F-SozU*. Göttingen: Hogrefe.

George, D., Dixon, S., Stansal, E., Gelb, S. L., & Pheri, T. (2008). Time diary and questionnaire assessment of factors associated with academic and personal success among university undergraduates. *Journal of American College Health*, *56*(6), 706–715.

Goetz, T., Frenzel, A. C., Stoeger, H., & Hall, N. C. (2010). Antecedents of everyday positive emotions: An experience sampling analysis. *Motivation and Emotion*, *34*(1), 49–62.

Goetz, T., Frenzel, A. C., Hall, N. C., Nett, U. E., Pekrun, R., & Lipnevich, A. A. (2014). Types of boredom: An experience sampling approach. *Motivation and Emotion*, *38*(3), 401–419.

Grund, A., & Fries, S. (2014). Study and leisure interference as mediators between students' self-control capacities and their domain-specific functioning and general well-being. *Learning and Instruction*, *31*, 23–32.

Grund, A., Schmid, S., & Fries, S. (2015). Studying against your will: Motivational interference in action. *Contemporary Educational Psychology*, *41*, 209–217.

Hofer, M., Kuhnle, C., Kilian, B., & Fries, S. (2012). Cognitive ability and personality variables as predictors of school grades and test scores in adolescents. *Learning and Instruction, 22*(5), 368–375.

Holder, M. D., Coleman, B., & Sehn, Z. L. (2009). The contribution of active and passive leisure to children's well-being. *Journal of Health Psychology*, *14(3)*, 378–386.

Inzlicht, M., & Schmeichel, B. J. (2012). What is ego depletion? Toward a mechanistic revision of the resource model of self-control. *Perspectives on Psychological Science*, *7*(5), 450–463.

Jacobi, C., Brand-Jacobi, J., Westenhöfer, J., & Weddige-Diedrichs, A. (1986). Zur Erfassung von Selbstkontrolle. Entwicklung einer deutschsprachigen Form des Self-Control-Schedule und der Desirability of Control Scale. *Diagnostica*, *32*(3), 229–247.

Kember, D., NG, S., TSE, H., Wong, E. T., & Pomfret, M. (1996). An examination of the interrelationships between workload, study time, learning approaches and academic outcomes. *Studies in Higher Education*, *21*(3), 347–358.

Kolari, S., Savander-Ranne, C., & Viskari, E.-L. (2007). Do our engineering students spend enough time studying? *European Journal of Engineering Education*, *31*(5), 499–508.

Kozar, J. M., Marcketti, S. B., & Gregoire, M. B. (2006). How textiles and clothing students spend their time and the stressors they reportedly experience. *Family and Consumer Sciences Research Journal*, *35*(1), 44–57.

Landrum, R. E., Turrisi, R., & Brandel, J. M. (2006). College students' study time: Course level, time of semester, and grade earned. *Psychological Reports, 98*(3), 675–682.

Linnenbrink-Garcia, L., & Pekrun, R. (2011). Students’ emotions and academic engagement: introduction to the special issue. *Contempary Educational Psychology, 36*, 1–3.

Marshall, S. J. (2018). Student time choices and success. *Higher Education Research and Development.* doi: 10.1080/07294360.2018.1462304

McGregor, D. E., Carson, V., Palarea-Albaladejo, J., Dall, P. M., Tremblay M. S., & Chastin S. F. M. (2018). Compositional Analysis of the Associations between 24-h Movement Behaviours and Health Indicators among Adults and Older Adults from the Canadian Health Measure Survey. *International Journal of Environmental Research and Public Health, 15*, 1779.

Mega, C., Ronconi, L., & De Beni, R. (2014). What makes a good student? How emotions, self-regulated learning, and motivation contribute to academic achievement. *Journal of Educational Psychology, 106*(1), 121–131.

Metzger, C., & Schulmeister, R. (2011). Die tatsächliche Workload im Bachelorstudium. Eine empirische Untersuchung durch Zeitbudget-Analysen. In *Der Bologna-Prozess aus Sicht der Hochschulforschung*, (pp. 68–78). Centrum für Hochschulentwicklung, Arbeitspapier 148.

Nezlek, J. B. (2012). Multilevel modeling analysis of diary style data. In M. R. Mehl & T. S. Conner (Eds.), *Handbook of Research Methods for Studying Daily Life* (pp. 357–383). New York: The Guilford Press.

Nonis, S. A., Philhours, M. J., & Hudson, G. I. (2006). Where does the time go? A diary approach to business and marketing students’ time use. *Journal of Marketing Education, 28*(2), 121–134.

Plant, E. A., Ericsson, K. A., Hill, L., & Asberg, K. (2005). Why study time does not predict grade point average across college students: Implications of deliberate practice for academic performance. *Contemporary Educational Psychology, 30*(1), 96–116.

Priebe, K., Kleindienst, N., Zimmer, J., Koudela, S., Ebner-Priemer, U., & Bohus, M. (2013). Frequency of intrusions and flashbacks in patients with posttraumatic stress disorder related to childhood sexual abuse: An electronic diary study. *Psychological Assessment*, *25*(4), 1370-1376.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). *Advanced quantitative techniques in the social sciences: Vol. 1*. Thousand Oaks: Sage.

Ridder, D. T. de, Lensvelt-Mulders, G., Finkenauer, C., Stok, F. M., & Baumeister, R. F. (2012). Taking stock of self-control: A meta-analysis of how trait self-control relates to a wide range of behaviors. *Personality and Social Psychology Review*, *16*(1), 76–99.

Ruiz-Gallardo, J.-R., Castaño, S., Gómez-Alday, J. J., & Valdés, A. (2011). Assessing student workload in problem-based learning: Relationships among teaching method, student workload and achievement. A case study in Natural Sciences. *Teaching and Teacher Education, 27*(3), 619–627.

Runyan, J. D., Steenbergh, T. A., Bainbridge, C., Daugherty, D. A., Oke, L., & Fry, B. N. (2013). A smartphone ecological momentary assessment/intervention "app" for collecting real-time data and promoting self-awareness. *PloS One*, *8*(8), e71325.

Schulmeister, R., & Metzger, C. (2011). *Die Workload im Bachelor: Zeitbudget und Studierverhalten: Eine empirische Studie*. Münster: Waxmann.

Scully, G., & Kerr, R. (2014). Student workload and assessment: Strategies to manage expectations and inform curriculum development. *Accounting Education*, *23*(5), 443–466.

Slavin, R. E. (1996). Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary Educational Psychology*, *21*(1), 43–69.

Stinebrickner, R., & Stinebrickner, T. R. (2004). Time-use and college outcomes. *Journal of Econometrics*, *121*(1), 243–269.

Stone, A. A., & Shiffman, S. (2002). Capturing momentary, self-report data: A proposal for reporting guidelines. *Annals of Behavioral Medicine*, *24*(3), 236–243.

Stone, A. A., Shiffman, S., Schwartz, J. E., Broderick, J. E., & Hufford, M. R. (2002). Patient non-compliance with paper diaries. *British Medical Journal*, *324*(7347), 1193–1194.

Tanner, J., Stewart, G., Maples, G., & Totaro, M. (2008). How business students spend their time – do they really know? *Research in Higher Education Journal*. Retrieved from http://www.aabri.com/manuscripts/09152.pdf

Thiel, F., Veit, S., Blüthmann, I., & Lepa, S. (2008). *Ergebnisse der Befragung der Studierenden in den Bachelorstudiengängen an der Freien Universität Berlin: Sommersemester 2008.* Berlin.

Trull, T. J., & Ebner-Priemer, U. (2013). Ambulatory Assessment. *Annual Review of Clinical Psychology*, *9*, 151–176.

Vallerand, R. J., & Bisonnette, R. (1992). Intrinsic, extrinsic, and amotivational styles as predictors of behavior: A prospective study. *Journal of Personality*, *60*(3), 600–618.

Wilhelm, P., & Schoebi, D. (2007). Assessing mood in daily life: Structural validity, sensitivity to change, and reliability of a short-scale to measure three basic dimensions of mood. *European Journal of Psychological Assessment*, *23*(4), 258–267.

Xerri, M.J., Radford, K., & Shacklock, K. (2018). Student engagement in academic activities: a social support perspective. *Higher Education, 75*(4), 589-605.

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal*, *45*(1), 166–183.

3.2. Manuskript 2: Examination stress in academic students: a multimodal, real-time, real-life investigation of reported stress, social contact, blood pressure, and cortisol

An adapted version of this chapter has been published as Koudela-Hamila, S., Smyth, J., Santangelo, P., & Ebner-Priemer U. W. (2020). Examination stress in academic students: a multimodal, real-time, real-life investigation of reported stress, social contact, blood pressure, and cortisol. *Journal of American College Health*. Online ahead of print: www.tandfonline.com.

Abstract

Objective: Academic examinations are a frequent and significant source of student stress, but multimodal, psychophysiological studies are still missing. *Participants & Methods:* Psychological and physiological variables were assessed on 154 undergraduate students in daily life using e-diaries resp. blood pressure devices at the beginning of the semester, and again before an examination. *Results:* Multilevel analysis revealed lower calmness, more negative valence, higher task-related stress, higher demands, lower perceived control, lower frequency of social contact, and a higher desire to be alone during the examination period (all p values < .0001), as well as lower ambulatory systolic blood pressure ($p = .004$), heightened cortisol at awakening ($p = .021$), and a smaller increase in cortisol ($p = .012$). *Conclusions:* Our study revealed empirical evidence that examination periods are not only associated with indicators of dysphoria, stress, and social withdrawal but also by altered physiological processes, which might reflect anticipatory stress and withdrawal effects.

3.2.1. Introduction

Examinations are a significant source of student stress because they are prevalent throughout a student´s life and relate to prospective career opportunities (Spangler et al., 2002). Although studies describing actual everyday life examinations are rare (e.g. Glaser et al., 1994; Kurokawa et al., 2011; Malarkey et al., 1995), such studies have the advantage of heightened ecological validity. In addition, multimodal assessment—including psychological, physiological, and social components—would be favorable for describing the stress response in students. The advent of smartphones and wearables has substantially improved the possibilities to investigate everyday life exams, including psychological, interpersonal, and psychophysiological processes in real time. These multimodal approaches—including physiological assessments—are known as ambulatory assessment (Fahrenberg et al., 2007), or ecological momentary assessment (Stone & Shiffman, 2002).

Psychological and Social Components of an Examination Stress Response

Although multiple studies focus on everyday life stress and coping in academic students (e.g. Brose et al., 2017; Juth et al., 2015), there is a significant lack of studies investigating responses to the most important stressor for students, namely real-life examinations. For example, Doerr et al. (2015) assessed stress, fatigue, and sleep quality among 50 university students using e-diaries at the beginning of the semester and before an examination, and assessed saliva cortisol in a subsample. They found a reciprocal stress–fatigue relationship, which appeared to be mediated by sleep quality and a significantly lower first cortisol value after awakening at the beginning of the semester than during the examination period. Pilcher et al. (1997) collected sleep logs of sleep quality and quantity over seven days at the beginning of the semester and prior to the final examinations. Inconsistent with findings from retrospective questionnaire studies on sleep quality in students facing an examination (e.g. Ahrberg et al., 2012; Jernelöv et al., 2009; Zunhammer et al., 2014), both Pilcher et al. (1997) and Doerr et al.

(2015) did not find differences in sleep quality during the examination period compared to the beginning of the semester.

Social contact and physical activity in 48 computer science students were assessed by Harari et al. (2017) five weeks before, two weeks during, and three weeks after an academic examination period. Physical activity was assessed with the activity sensor of the smartphone, whereas social contact was approximated by time with other voices assessed with the smartphone's microphone. They found a decline in the time spent with others, and the time spent being active as the examination period drew closer.

Studies show that the transition into university life can be demanding (Briggs et al., 2012; Tett et al., 2017). Although this is an important issue for the planning of programs that aim to facilitate this transition, there are no studies, to our knowledge, that use ambulatory assessment to compare the experiences of freshman to the experiences of students in later semesters in daily life.

Physiological Components of the Stress Response: Cortisol

Studies assessing the cortisol awakening response (CAR) in the academic examination period are common, but findings are mixed and strongly dependent on context variables. The CAR has been hypothesized to be a marker of the hypothalamus–pituitary–adrenal axis activity (Kudielka & Wüst, 2008), which typically shows a steep increase in the first 30 minutes after awakening and is generally thought to reflect a preparatory stress response for daily activities (e.g. Powell & Schlotz, 2012). Surprisingly, studies investigating the CAR in the context of everyday life academic exams have yielded mixed findings, as they have found elevated (Weik & Deinzer, 2010) but also lowered (Duan et al., 2013; Vedhara et al., 2000) CAR indices during examination periods. Besides, studies have shown that the CAR can be altered by psychosocial context factors (see Chida & Steptoe, 2009 for a review), social contact (Stetler & Miller, 2005), and sleep parameters (see Fries et al., 2009 for a review), all of which could differ between examination periods and the beginning of the semester. The mixed findings might be explained by the low number of participants and the influence of social context, the latter of which, to our knowledge, has not been included in studies investigating the CAR in academic examination periods.

Physiological Components of the Stress Response: Blood Pressure

Studies investigating the blood pressure response to real examinations have also shown divergent results, with some studies revealing higher blood pressure in an examination period (Hughes, 2004) and others not finding elevations (e.g. Lovallo et al., 1986). Zhang et al. (2011) found only small increases during three examination days, compared to the days before - this effect was more pronounced for students scoring high in anxiety. Mixed findings can be explained by varying study designs (blood pressure reactivity vs. blood pressure levels during examinations; Hughes, 2004; Zhang et al., 2011), or again by changing psychosocial context (Cornelius et al., 2018) and physical activity, which was not taken into account in most studies.

Unfortunately, there are only a few studies that combine the assessment of blood pressure with e-diaries to investigate academic stressors in student samples. Conley and Lehman (2011) is one notable exception, which combined hourly ambulatory blood pressure readings of 99 students (from 8 to 11 a.m.) with end-of-day reports about stressors and the time they occurred. Hierarchical linear models revealed elevations in systolic blood pressure at times when an acute academic stressor was reported, but assessments were not done during an examination period, and they used a retrospective stressor assessment, too.

A Conceptual Multimodal Approach to the Assessment of Examination Stress in Daily Life

Summarizing the abovementioned studies leads to a divergent and, in the case of CAR, even contradictory picture of students' stress response. This might be explained because not all studies a) took a multimodal approach, combining psychosocial and physiological stress response components, b) assessed real academic examinations while using everyday life measures, such as e-diaries, to track the psychological stress components, and c) control for important variables, such as physical activity and social interactions.

In our attempt to implement a more comprehensive multimodal assessment of student experience in daily life, we compared the everyday experiences of students in real-life situations during a demanding period of examinations, with a less demanding period at the beginning of the semester. We examined the putative impact of academic examinations in three domains, namely in psychological, social, and physiological processes. More specifically, regarding psychological parameters, we not only assessed perceived stress but also perceived demand and feeling of control, in a closer look at the psychological variables that contribute to the stress responses. We hypothesized that university students would report more stress, more demands, and less control, less calmness, more negative mood, and lower sleep quality, on average, during the examination period compared to the beginning of the semester. Regarding social parameters, we expected less social contact in the examination period compared to the beginning of the semester. Concerning physiological parameters, we hypothesized an altered CAR, higher blood pressure, and reduced blood pressure dipping in the examination period compared to the beginning of the semester. As additional analyses, we compared students in their first or third semester regarding the psychological, social and physiological components assessed, because cumulative experience within the university system might change the experiences of students in daily university life.

3.2.2. Methods

Study Design

To contrast the stress experiences during the examination period with a non-examination period on a within-subject level, we defined two assessment points: one week at the beginning of the semester when the lectures had started, but no major examinations would occur, and one week during the formal examination period at the end of the semester. To capture the stress experience of preparing for the examination, the assessment for each student started individually eight days before an examination and ended the evening before the examination itself. During both assessment weeks, students carried a smartphone (HTC Touch Diamond II, Windows Mobile 6.5) with a preinstalled e-diary. Additionally, half of the students wore a computer-controlled blood pressure recorder (boso, TM-2430. Jungingen, Germany: Bosch & Sohn) for 24 hours. As physical activity does influence blood pressure (Leary et al., 2000), students wore an activity-monitoring device (KMS move. Karlsruhe, Germany: Movisens). To determine the CAR, the other half of the students collected saliva samples on two days during both assessment weeks, respectively. Personal-level questionnaires were administered during both assessment weeks, but are not included in this paper. The data collection took place at the Karlsruhe Institute of Technology (KIT) in Germany during the winter semester, which generally starts with lectures in the middle of October and ends in the middle of February. After the end of the lectures, an examination period of several weeks follows.

Students who were enrolled in courses that were preselected for practical reasons (such as courses that were primarily attended by *industrial engineering and management* students in their first and third semesters) were asked to participate. Students were informed about the study in groups of approximately 20, started the e-diary, and received either the blood pressure and activity devices or the saliva cortisol tubes. After the first study week, the students returned all devices and cortisol tubes. Later in the semester, the students informed the research team about their examination dates. Based on the provided dates, appointments for the second measurement were made individually exactly one week before an examination. After the examination, the students returned the devices and cortisol tubes. To enhance engagement and compliance, the students received an individual report of their results of both periods after finishing the study, with a personal coaching session on how to address their stressors. All students provided written informed consent. Ethical approval for our study was not mandatory, according to local and national law.

Participants

One hundred fifty-four students provided informed consent. As expected for a technical university, most of the participants were male (79%) and were studying *industrial engineering and management* (85%). The mean age of all participants was 21.1 years (*SD* = 1.5). Most (76%) of the students were in their first or third semesters, and 99% of the participants were of German nationality. The mean body mass index (BMI) was 22.1 (*SD* = 2.2).

Measurements: E-Diary

The e-diary emitted a signal every full hour (e.g., 9:00 a.m., 10:00 a.m., 11:00 a.m.) during the waking hours of each day during both of the assessment weeks; this nonrandom sampling scheme was necessary to achieve synchronicity between the e-diary ratings and blood pressure readings. We allowed for a ten-minute maximum response delay – if the student did not answer within this period, the data were labeled as missing. Students put the e-diary in sleep mode before going to bed and started it again in the morning. The e-diary software MyExperience Movisens Edition (Karlsruhe, Germany: Movisens; Froehlich et al., 2007) time-stamped all responses automatically over the entire week. Due to technical problems, smartphone data from two students were missing for the start of the semester, and three datasets were missing during the examination period. Five participants dropped out before the second measurement, resulting in a final e-diary sample of 152 students at the start of the semester and 146 in the examination period.

For the e-diary assessments, we only applied previously used items with established translations. English versions are presented in the following section, and German versions are available upon request.

Task-related stress: To capture task-related stress, we used the following previously used e-diary items: *I'm not skilled to do this activity, I would rather do something else, this activity requires effort* (Myin-Germeys et al., 2001), as well as, *the tasks are too much for me right now*; all of the items were rated on a scale from 1–7.

Demand and control (Fahrenberg, 1996): To assess the demands of the current task, we asked, *is your momentary task demanding (-3) or relieving (+3)?* This item was recoded to a 1–7 scale. Control was assessed by the following question: *Is the current situation under your control? (scale 1–7).*

Mood: To assess momentary mood, we used the momentary Multidimensional Mood Questionnaire (Wilhelm & Schoebi, 2007), which has shown good sensitivity to change and good between- and within-subject reliability estimates on all three dimensions (*rel(between calmness)* = .90, *rel(between energetic arousal)* = .90, and *rel(between valence)* = .92; *rel(within calmness)* = .70, *rel(within energetic arousal)* = .77, and *rel(within valence)* = .70). All items were scaled 0–6.

Sleep quality: The first smartphone question every day assessed the sleep quality of the students *(How did you sleep last night? very good (+3) – very bad (-3)).*

Social Contact: To examine social contact, we assessed the presence of others (*Are you together with people right now?*), the pleasantness of social interaction (*I don't like/like the present company; scale -3-+3*) and the reported desire to be alone (*I would rather be alone; scale 1–7*). The items were previously used in an e-diary study by Jacobs et al. (2007).

Time used for learning: Students were asked to report their time use in minutes since the last beep, on several categories, which included time spent learning (*How much time did you spend on the following activities since the last beep?).*

Measurements: Cortisol Awakening Response (CAR)

Saliva samples were collected by the students using the Salivette (Rommelsdorf, Germany: Sarstedt). To capture the CAR, students provided saliva samples immediately after awakening, as well as 30 minutes, 45 minutes, and 60 minutes later. Students were told not to eat, brush their teeth, smoke, or engage in any physical exercise, and to only drink water before the cortisol assessment was finished. To facilitate and track timely compliance, the smartphone presented a random three-digit code each time saliva was collected, which the students had to write on the label of the Salivette tube they were currently using (Kudielka et al., 2007).

Cortisol awakening response (CAR): Three different components were derived: 1) the cortisol level upon awakening (S1), 2) the area under the curve with respect to increase (AUCi) as an indicator of cortisol change after awakening, and 3) the area under the curve with respect to ground (AUCg), which incorporates the overall cortisol level and the cortisol change after awakening, and is thought to be more related to the overall secretory activity of the hypothalamus-pituitary-adrenal axes (Clow et al., 2004; Pruessner et al., 2003). Given that a reduced AUCi could be due to hypocortisolism (a reduced peak) but also to a heightened S1, it is highly recommended to use both indicators (see Clow et al., 2004). As studies show (Chida & Steptoe, 2009; Pruessner et al., 2003) that the AUCi and the AUCg covary with different variables, there is a debate as to whether the AUCi and AUCg represent different regulatory processes (Chida & Steptoe, 2009); as such, we included indices reflecting both.

Seventy-seven students took part at the beginning of the semester. Two students dropped out before the second assessment period, and three students did not return the Salivette tubes in time, resulting in a sample of 72 students for the examination period. At the beginning of the semester, data from one student from one day had to be excluded from the analysis because the student fell asleep again before beginning the sample collection. Additionally, we excluded one set of student data on three different days during the examination period because one student ate before collecting the samples, one student had an unrealistically high cortisol value of S1 = 60 mmol/l on the second day, and one student had only one assessment on the second day. Additionally, we excluded all cortisol samples that had a self-reported delay of more than five minutes according to the protocol. These exclusions resulted in five excluded days, both at the beginning of the semester and during the examination period. Another two samples were missing at the beginning of the semester because two students each lost one cortisol tube (60 minutes after awakening).

Measurements: Ambulatory Blood Pressure

For blood pressure measurements, we used a 24-hour computer-controlled blood pressure recorder (boso, TM-2430). The blood pressure cuff was fitted on the nondominant arm of the students. Systolic and diastolic blood pressure readings were taken every 15 minutes during the waking time, and every 30 minutes during the night over 24 hours. Seventy-seven students participated in the blood pressure assessment at the beginning of the semester. Three students in the blood pressure group dropped out at the second assessment. Additionally, blood pressure data were missing in four cases due to technical problems, resulting in 70 blood pressure recordings during the examination period. Nighttime data recordings did not work for two students at the beginning of the semester and one student during the examination period, resulting in nighttime blood pressure data for 75 students at the start of the semester and 69 students during the examination period. The mean number of day- and nighttime blood pressure recordings were equal across the two assessment weeks (M_{day} = 57, SD_{day} = 6, M_{night} = 14, SD_{night} = 3).

Blood pressure dipping (BPD): The reduction in systolic or diastolic blood pressure from daytime average to nighttime average, so-called blood pressure dipping, was calculated as an indicator of the ability to unwind after work (Rau & Triemer, 2004): BPD = ((mean BP day – mean BP night)/mean BP day) *100. Excluding participants because of low numbers of the day- or nighttime recordings was not necessary because all participants were above the threshold of six nighttime and 20 daytime records.

Values were treated as unrealistic values and excluded from the analysis if they were outside the following range: $50 < SYS < 240$, $20 < DIA < 150$ (Rau & Triemer, 2004). Additionally, pulse pressure (SYS-DIA) had to be greater than ten and smaller than 110 to be included in the analysis. These criteria resulted in 235 blood pressure outliers (2.3%) in total.

Measurements: Physical Activity

To control for the effect of physical activity on blood pressure, students from the blood pressure group were additionally equipped with an activity-monitoring device (KMS move. Karlsruhe, Germany: Movisens), attached with an elastic strap to the chest. According to established procedures (von Haaren et al., 2016), we high-pass filtered the raw acceleration signal in each axis to exclude the gravitational DC component. We applied a low-pass filter to eliminate non-body movement accelerations (van Someren et al., 1996), and combined the three axes by calculating the vector magnitude. This resulted in a minute-by-minute index for physical activity (movement acceleration intensity in mg). Seventy-seven students participated in the activity assessment at the beginning of the semester, with two missing due to technical problems. Three students dropped out during the second assessment period, with an additional eight missing due to technical problems. This resulted in 75 activity data sets at the beginning of the semester, and 66 data sets at the examination period.

Data Analyses

Due to the nested data structure, we used multilevel regression models with a two-level structure. One main advantage of such multilevel models is that different numbers of data points per person, likely due to some inevitable missing data in ambulatory assessment studies, can be accounted for. We used separate models for the e-diary ratings, blood pressure, and cortisol data as outcomes. We modeled occasions (level 1) nested within persons (level 2) to predict e-diary data and the hourly blood pressure data. We modeled days (level 1) nested within persons (level 2) to predict blood pressure dipping and the CAR. In each of the models, a variable identifying the two assessment weeks (the beginning of the semester and the examination period) was used as a predictor. For the analysis of the e-diary data, all ratings were included as single scores into the multilevel models. For the analysis of blood pressure, the mean over the last four succeeding 15 min. blood pressure readings was calculated (min 0, min -45, min -30, min -15) to get an estimate of blood pressure over the last hour. Blood pressure dipping, S1, AUCi, and AUCg were calculated per day of assessment, resulting in two scores of blood pressure dipping and four scores of S1, AUCi, and AUCg per participant.

Restricted maximum likelihood estimation procedures were used for all models. A first-order autoregressive error structure was implemented for all repeated, continuous outcomes. All intercepts and the slopes from the hourly blood pressure analysis were allowed to vary randomly. For the models using blood pressure dipping and the CAR indices as outcomes, only the intercepts were allowed to vary randomly because of the restriction in level 1 numbers (two days of blood pressure dipping and four days of CAR assessment). In cases where random slopes failed to explain variance significantly, slopes were fixed. To make a clear and interpretable separation of the within- and between-subject effects, all predictor variables at level 1 were group-mean centered (Enders & Tofighi, 2007). Predictor variables at level 2 were only grand-mean centered if this was thought to facilitate the interpretation of the intercept.

We used participant sex as a person-level control variable throughout the analyses. BMI was used as a personal-level control variable in the physiological analyses; we centered BMI on two different means (based on sex) because we had already used sex as a control variable (Robotham, 2008; Stalder et al., 2016). If blood pressure was the outcome, we used the time spent learning since the last beep, momentary social contact and the aggregated mean activity five minutes before every single blood pressure assessment, the frequency of social contact during the whole blood pressure assessment for each person, and the mean activity over the entire day as additional control variables. We used the time spent learning during the whole day, and the mean activity over the whole day as control variables if blood pressure dipping was the outcome. Time spent learning was included because this activity is done mostly while sitting and thus has a considerable impact on blood pressure in addition to physical activity. Distinguishing objectively between sitting and standing was not possible, as we only had one sensor on the chest. In the analyses of the cortisol data, we used awakening time as a between (mean awakening time per person) and within (varying awakening time at day level; Stalder et al., 2016), and social contact aggregated on the personal level as control variables. For the binary coded outcome *presence of others*, we used two approaches: multilevel logistical analysis and multilevel analysis of continuous data. As the results were concordant, we will report the results in accordance with the other continuous variables. Data management and analysis were done using SAS© 9.4 (Cary, NC, USA: SAS Institute). An alpha level of 5% (two-sided) was used for all statistical analyses. To decrease the possibility of alpha-inflation caused by multiple testing, we corrected all significance tests using the Bonferroni-Holm correction (Holm, 1979).

3.2.3. Results

Participants and Compliance

The final sample included 152 participants at the start of the semester and 146 during the examination period. Because many examinations were administered in the examination period, for ten students, the study week before the examination included another examination. Missing data for e-diary ratings differed between the start of the semester (5.5%) and the examination period (10.2%). However, the heightened missing data rate at the examination period was not systematically related to the ratings given in the e-diary. Specifically, we investigated the relation between ten main e-diary parameters of interest and missing data at the examination period and revealed just one significant finding (valence: $r = -0.19$; $p = .022$). In addition, the post-monitoring questionnaire (Ebner-Priemer et al., 2007) did not reveal different ratings for burden (*How unpleasant were the self-ratings with the smartphone?* - Beginning of the semester: $M = 1.82$, $SD = 0.83$; examination period: $M = 1.82$, $SD = 0.79$; scale 1–7) and reactivity (*Did you pay more attention to your psychological state during the assessment?* - Beginning of the semester: $M = 2.53$, $SD = 1.24$; examination period: $M = 2.52$, $SD = 1.13$; scale 1–7). The mean of answered inquiries per day was 14.52 ($SD = 2.61$). No participants had to be excluded because of low compliance. In Table 1, the descriptive statistics for all outcome measures are summarized. Although the mean values were in the medium range of the scales used, there were large differences between students in the examination period, with individual means ranging from 1.3 to 6.5 regarding stress, 2.2 to 6.6 regarding demands, and 1.7 to 6.9 regarding control. However, looking at the highest individual rating per person in the examination period did reveal that no student consistently experienced no stress during the examination period. The highest individual rating per person ranged from 4 to 7 for stress and from 5 to 7 for demand.

Table 1. Descriptive statistics

	Beginning of semester				Examination period			
E-Diary (mean per student: aggregated over one week)	*M*	*SD*	*Min*	*Max*	*M*	*SD*	*Min*	*Max*
Task related stress	2.64	0.88	1.08	5.78	3.54	0.97	1.29	6.53
Demand	3.46	0.59	1.96	5.30	3.99	0.71	2.23	6.64
Control	5.78	0.80	2.54	7.00	5.32	0.98	1.75	6.99
Calmness	4.43	0.76	2.72	5.92	4.16	0.94	0.97	5.92
Energetic arousal	3.72	0.73	1.91	5.72	3.72	0.87	1.50	5.60
Valence	4.53	0.77	2.50	5.99	4.23	0.92	1.24	5.99
Sleep quality	1.13	0.97	-1.71	3.00	1.21	0.92	-2.43	2.86
Frequency of social contact	0.56	0.15	0.14	0.95	0.41	0.21	0.02	0.91
Pleasantness of social interaction	2.09	0.62	0.28	3.00	2.08	0.79	-3.00	3.00
Desire to be alone	1.90	0.89	1.00	5.72	2.15	0.98	1.00	7.00
Cortisol [nmol/l] (mean per student: aggregated over two days)								
S1	8.07	3.42	1.07	17.20	9.27	4.61	0.54	27.05
AUCi	172.10	189.20	-224.50	743.30	77.84	214.20	-724.60	817.00
AUCg	650.30	203.90	63.78	1187.70	630.50	247.00	21.05	1529.10
Blood Pressure [mmHg] (daily mean per student)								
Systolic blood pressure	131.20	9.98	103.00	160.00	128.50	10.71	101.40	149.50
Diastolic blood pressure	76.17	5.64	61.24	90.46	75.55	6.91	57.24	92.51
Blood Pressure dipping [%]								
Systolic blood pressure dipping	14.35	7.09	-4.51	26.92	13.58	7.02	-3.74	27.54
Diastolic blood pressure dipping	19.51	8.56	0.04	38.17	18.84	0.91	-12.01	33.90

E-Diary Ratings

Differences in the subjective ratings between the beginning of the semester and the examination period are displayed in Figure 1a, b, and c. As hypothesized, the examination period was associated with significantly higher task-related stress (β = 0.85, *SE* = 0.03, *t* = 31.26, *p* < 0.001), higher demands (β = 0.49, *SE* = 0.03, *t* = 16.14, *p* < 0.001), and less control (β = -0.43, *SE* = 0.02, *t* = -21.88, *p* < 0.001) (Figure 1a).

Regarding mood, students were less calm (β = -0.26, *SE* = 0.02, *t* = -14.49, *p* < 0.001) and reported less positive valence (β = -0.31, *SE* = 0.02, *t* = -16.42, *p* < 0.001) during the examination period than at the beginning of the semester. Energetic arousal did not reach significance (β = 0.02, *SE* = 0.03, *t* = 0.84, *p* = 0.402), nor did reported sleep quality (β = 0.09, *SE* = 0.06, *t* = 1.44, *p* = 0.152) (Figure 1b). Frequency of social contact was significantly lower during the examination period than at the beginning of the semester (β = -0.14, *SE* = 0.01, *t* = -15.94, *p* < 0.001). Additionally, there was a higher desire to be alone during the examination period (β = 0.21, *SE* = 0.03, *t* = 7.23, *p* < 0.001), although the pleasantness ratings of the social contact did not significantly change (β = 0.03, *SE* = 0.03, *t* = 0.94, *p* = 0.347) (Figure 1c). All findings were controlled for participant sex (which did not reach significance).

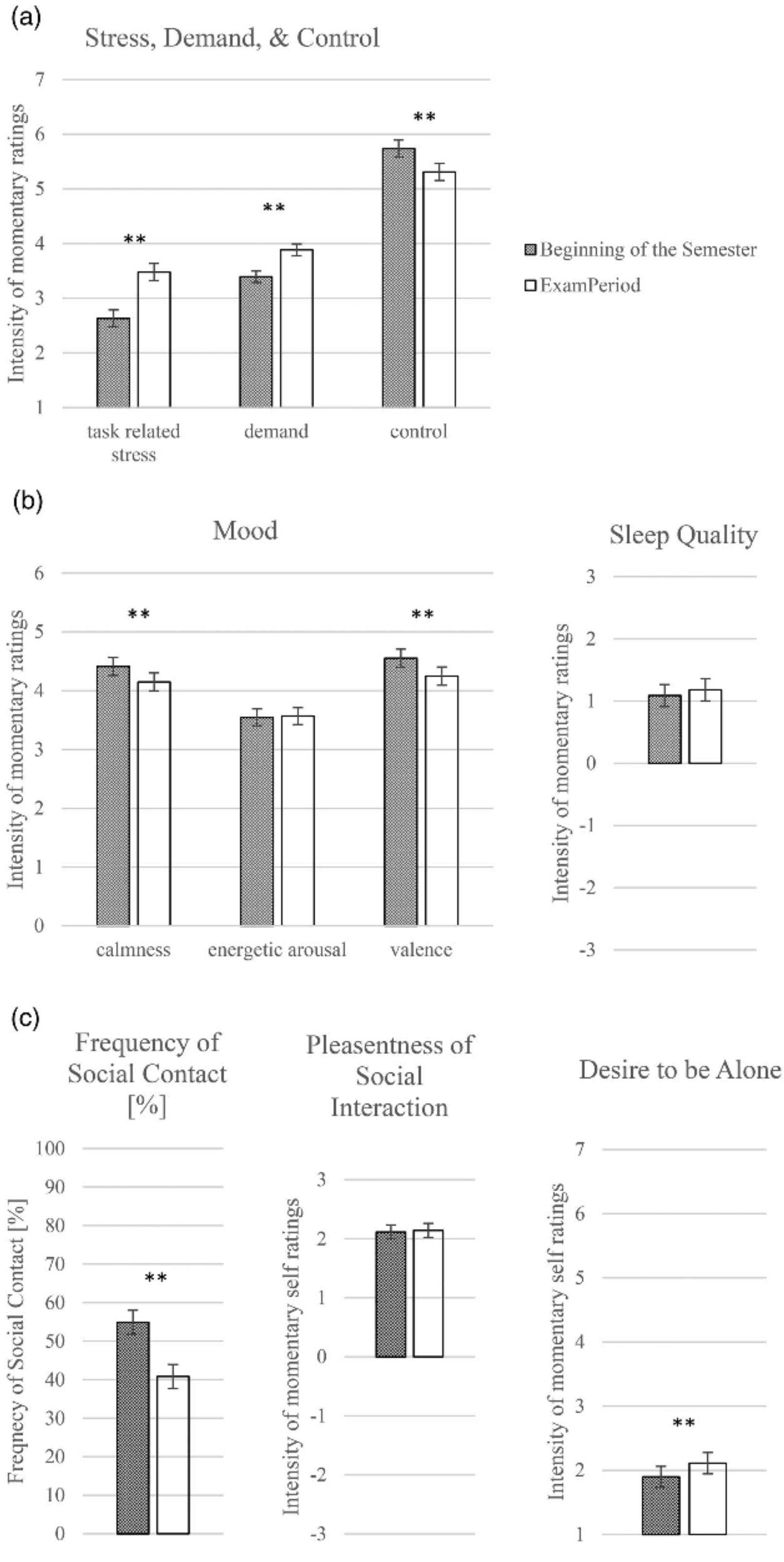


Figure 1. Differences of least squares means with 95% confidence interval between the beginning of the semester and the examination period for task-related stress, demand, feelings of control (Figure 1a), mood (calmness, energetic arousal, valence) and sleep quality (Figure

1b), social contact (frequency of social contact, pleasantness of social interaction, desire to be alone; Figure 1c). $^{**}p < .001$

Cortisol Awakening Response

The CAR, as part of the higher stress level in the examination period, was altered as hypothesized. The first value after awakening was higher, and there was a less steep increase in the CAR in the examination period compared to the beginning of the semester (see Figure 2). In our multilevel models, we first controlled for awakening time and social contact at the between level. As social contact did not show any significant association with the used CAR indices on the between level ($p_{S1} = 0.736$; $p_{AUCi} = 0.854$; $p_{AUCg} = 0.732$), we dropped it from the analyses (see Table 1). The first value after awakening (S1) was significantly higher in the examination period than at the beginning of the semester ($p = 0.021$), reflecting higher starting levels during the examination period. Additionally, the increase after awakening (AUCi) differed significantly between the beginning of the semester and the examination period ($p = 0.012$), with a lower increase (AUCi) in the examination period (see Table 1 and Figure 2). However, there was no significant effect of period on AUCg ($p = 0.479$). Being a person who wakes up earlier was associated with a trend toward a lower first value after awakening (S1; $p = 0.051$) and toward a higher increase after awakening (AUCi; $p = 0.096$). Waking up later than usual was associated with higher cortisol levels upon awakening (S1; $p = 0.040$).

Table 2. Multilevel models of the three different CAR markers

	S1		AUCi		AUCg	
	β (SE)	*t*	*β (SE)*	*t*	*β (SE)*	*t*
Intercept	7.97** (0.54)	14.90	154.92** (26.88)	5.76	622.55** (30.36)	20.54
Within						
Period (beginning of the semester vs. examination period)	1.31* (0.55)	2.37	-98.69* (30.34)	- 3.25	-18.35 (25.72)	-0.71
Between control						
BMI	-0.44* (0.18)	-2.39	-1.85 (8.73)	- 0.21	-28.74* (10.65)	-2.70
Sex	0.22 (0.88)	0.25	20.81 (41.71)	0.50	53.13 (51.81)	1.03
Time of awakening (mean per person)	0.65$^+$ (0.33)	1.99	-26.21$^+$ (15.54)	- 1.69	16.51 (18.98)	0.87
Within control						
Time of awakening	0.58* (0.28)	2.07	-20.47 (15.19)	- 1.35	11.99 (12.54)	0.96

$^+p < 10$; $*p < .05$; $**p < .001$

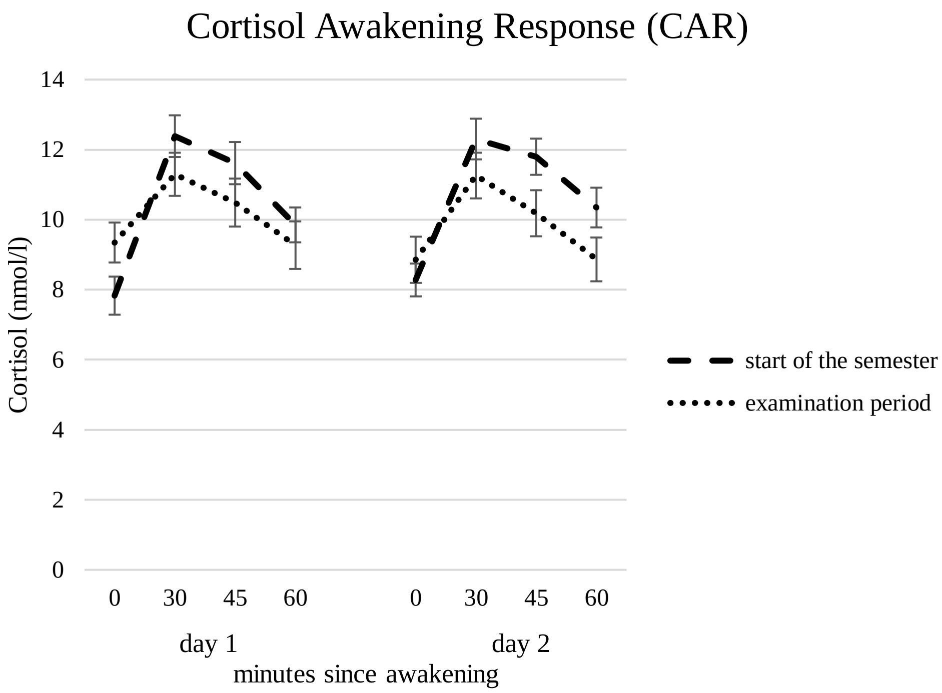


Figure 2. The mean and standard deviation of the cortisol awakening response per student over four days, separated by the assessment period.

Blood Pressure

Differences in blood pressure readings between the beginning of the semester and the examination period are represented by the dummy coded variable *period* in Table 3. The effect of period reached significance regarding systolic blood pressure ($p = 0.004$) but missed reaching significance regarding diastolic blood pressure ($p = 0.718$). However, contrary to our hypothesis, systolic blood pressure was lower in the examination period than at the beginning of the semester. As this was surprising, we performed additional analyses without controlling for activity and social contact at the within and between levels, and time spent learning at the within level. Without these control variables, period revealed a significant effect on systolic ($p = 0.001$) but not on diastolic ($p = 0.218$) blood pressure. However, systolic blood pressure still showed lower values during the examination period. Within-subject covariates, such as physical activity and time spent learning as a proxy for sitting, did show meaningful relations in expected directions (details see Table 3), as well as between-subject control variables, such as BMI, and sex.

Table 3. Multilevel model of systolic (SBP) and diastolic (DBP) blood pressure. The mean of the four assessments per hour served as the criterion.

	SBP (mean h)		DBP (mean h)	
	β (SE)	*t*	*β (SE)*	*t*
Intercept	111.52** (5.24)	21.29	69.14** (4.26)	16.23
Within				
Period	-2.24* (0.80)	-3.01	-0.20 (0.56)	-0.36
Between control				
BMI	1.07* (0.41)	2.64	0.15 (0.33)	0.45
Sex	-13.46** (2.28)	-5.91	-1.95 (1.84)	-1.06
Activity (person mean)	0.35 (0.08)	4.17	0.11 (0.07)	1.63
Social contact (person mean)	-7.32 (4.54)	-1.58	-1.16 (3.72)	-0.31
Within control				
Activity hourly	0.11** (0.01)	12.17	0.08** (0.01)	9.78
Learning hourly (in hours)	-1.63 (1.04)	-1.56	-2.43* (0.74)	-3.31
Social contact	0.46 (0.61)	0.75	0.84^{+} (0.50)	1.69

$^{+}p < 10$; $*p < .05$; $**p < .001$

The systolic and diastolic blood pressure reduction at night (BPD: blood pressure dipping) did not significantly differ between the examination period and the beginning of the semester (SBPD: β = -0.26, *SE* = 1.03, *t* = -0.25, *p* = 0.802; DBPD: β = -0.50, *SE* = 1.25, *t* = -0.40, *p* = 0.694; details are available upon request).

Different patterns of experience of freshman compared to third semesters?

To answer our last hypotheses, we restricted our sample and only used students in their first or third semester, because only a few students in higher terms participated and their inclusion would lead to biased comparisons between the groups. We ran the analysis again with the models described above but included a dummy variable for the first (dummy variable = 0) vs. third semester (dummy variable = 1). There were no significant effects of this dummy variable. However, we also included an interaction term of this variable with our dummy variable for the beginning of the semester vs. the examination period and found significant interaction effects, which we describe subsequently. For the mood dimension valence ($p <$ 0.001) and calmness ($p < 0.001$), as well as for task-related stress ($p < 0.001$), perceived control ($p = 0.013$), demand ($p < 0.001$), and the frequency of social contact ($p = 0.049$), we found a significant interaction effect of semester with period. Simple differences of least squares means showed that, with regard to calmness (β = 0.31, *SE* = 0.16, *t* = 2.01, *p* = 0.046) and valence (β = 0.26, *SE* = 0.16, *t* = 1.68, *p* = 0.097), students in the third semester showed higher values at the beginning of the semester than students in their first semester, which was reflected in a steeper decline among third-semester students from the beginning of the semester to the examination period. Students in their first semester were significantly more stressed at the beginning of the semester than students in their third semester (β = 0.38, *SE* = 0.17, *t* = 2.26, *p* = 0.026). Students in their third semester did show more perceived control at the beginning of the semester than students in their first semester (β = 0.32, *SE* = 0.16, *t* = 2.07, *p* = 0.041). Demand changed more for students in their third semester from the beginning of the semester to the examination period (first semester: $\beta = 0.12$, $SE = 0.06$, $t = 1.92$, $p = 0.057$; third semester: $\beta = 0.66$, $SE = 0.04$, $t = 15.88$, $p < 0.001$), which was reflected in higher perceived demands during the examination period among these students than among those in their first semester ($\beta = 0.43$, $SE = 0.12$, $t = 3.77$, $p < 0.001$). A similar pattern was seen regarding the frequency of social contact – it declined more for the third semester students towards the examination period (first semester: $\beta = -0.11$, $SE = 0.02$, $t = -6.32$, $p < 0.001$; third semester: $\beta = -0.15$, $SE = 0.01$, $t = -12.99$, $p < 0.001$). Students in both semesters did show significant simple differences of least squares means from the beginning of semester to the examination period regarding calmness (first semester: $\beta = -0.09$, $SE = 0.04$, $t = -2.51$, $p = 0.014$; third semester: $\beta = -0.30$, $SE = 0.03$, $t = -12.05$, $p < 0.001$), valence (first semester: $\beta = -0.17$, $SE = 0.04$, $t = -4.78$, $p < 0.001$; third semester: $\beta = -0.34$, $SE = 0.03$, $t = -13.73$, $p < 0.001$), stress (first semester: $\beta = 0.37$, $SE = 0.05$, $t = 7.01$, $p < 0.001$; third semester: $\beta = 0.98$, $SE = 0.04$, $t = 26.41$, $p < 0.001$), perceived control (first semester: $\beta = -0.29$, $SE = 0.04$, $t = -7.70$, $p < 0.001$; third semester: $\beta = -0.40$, $SE = 0.03$, $t = -15.41$, $p < 0.001$), and frequency of social contact. There were no significant interactions of semester with period regarding sleep quality ($p = 0.919$), the desire to be alone ($p = 0.136$), and the pleasantness of social interaction ($p = 0.727$). For the physiological variables, none of the interaction terms were significant (S1: $p = 0.935$; AUCi: $p = 0.071$; AUCg: $p = 0.133$; SBP: $p = 0.274$; DBP: $p = 0.270$; SBPD: $p = 0.941$; DBPD: $p = 0.865$). Overall, the findings of the analyses of our sample did confirm the assumption that the transition into university life is demanding, with students showing elevated values at the beginning of the first semester, revealing a change in stress patterns throughout the course of the semester as students progress in university.

3.2.4. Discussion

As expected, academic examinations are characterized by a multimodal pattern of heightened psychological, social, and physiological stress components. The e-diary data revealed, as predicted, higher perceived demand, lower perceived control, more negative emotional valence, less calmness, and higher perceived stress during the examination period than at the beginning of the semester. These results replicate and extend prior work; for example, results from an e-diary study by Doerr et al. (2015) and questionnaire studies (Abouserie, 1994; Spangler et al., 2002) revealed that examinations are a substantial stressor for many students. On average, students are more stressed in the examination period than at the beginning of the semester. However, the absolute values of the aforementioned variables in the examination period were still in the middle range of the scale (see Figure 1), suggesting that they were not completely overwhelmed by the demands of the examination period. There were no differences between the two assessment periods regarding energetic arousal, suggesting that the students still had enough energy to cope with the higher demands of the examination period.

Analyzing differences in stress patterns between freshmen and third-semester students revealed that, as expected, the transition to university life is demanding. Students in their first semester showed more stress, less perceived control, and lower valence and were less calm at the beginning of the semester than students in their third semester. However, the examination period for the third-semester students was also characterized by heightened demands and less social contact than that of the first semester students, suggesting more difficult examinations in the third semester for the assessed student population. There were no significant differences between first- and third-semester students in perceived control during the examination period, suggesting that the adjustment to examinations could be a more challenging, long-lasting process. Of note, there seem to be considerable differences between students, which should be analyzed further because it may suggest moderators or sub-groups that are at differential risk of adverse outcomes associated with examination stress.

As hypothesized, we found altered CAR indices. During the examination period, values at awakening (S1) were higher, and the average increase (AUCi) was lower. A heightened S1 might be due to an anticipation of the upcoming demands in the examination period (Powell & Schlotz, 2012). Our results are in line with other studies (Duan et al., 2013; Vedhara et al., 2000) that found a lowered AUCi in the examination period. Also, concordant with our results are studies by Weik and Deinzer (2010) and Doerr et al. (2015), who found a heightened S1 in the examination period. Duan et al. (2013), however, did not find a difference in S1 between the two assessment periods. In accordance with Duan et al. (2013), but contrary to Weik and Deinzer (2010), our analyses revealed no differences in overall cortisol levels (AUCg) of the CAR. The results of Vedhara and colleagues (2000) point out the influence of cortisol on cognitive factors, which might be of special interest in interpreting the findings of stress and cortisol in the examination period. According to Vedhara et al. (2000), the altered AUCi could be due to learning processes because, in their study, lower cortisol values in the examination period were associated with enhanced short-term memory.

During the examination period, the frequency of social contact decreased, and the desire to be alone increased, whereas the pleasantness of the interactions remained the same. This social withdrawal is in line with previous research (Harari et al., 2017), and could be due to more time spent learning mostly alone, as well as a desire to avoid interruptions. As different aspects of social interactions influence different outcome variables—for example, academic success, drop-out rates, well-being, and health (Bernstein et al., 2018; Stadtfeld et al., 2019)—it is essential to differentiate the frequency and quality of social interactions.

Perceived sleep quality was not lower during the examination period in our study, which is in contrast to traditional questionnaire studies (Ahrberg et al., 2012; Jernelöv et al., 2009;

Zunhammer et al., 2014), but in line with other diary studies (Doerr et al., 2015; Pilcher et al. 1997). As diary studies come with the advantage of lower retrospective distortions, and questionnaire studies have the advantage of assessing multiple aspects of sleep quality, it remains unclear where the differences come from.

Our analysis revealed lower blood pressure in the examination period, contrary to our expectations and contrary to results from previous studies using somewhat different methods (Conley & Lehman, 2011; Hughes, 2004). In addition, time spent learning showed a significant negative association with diastolic blood pressure. The effect of time spent learning on blood pressure could be due to an artifact, namely learning is done mostly while sitting. Another possible explanation might involve cognitive processes associated with learning, such as attentional shifts, which could act as distractions from stressful ruminative thoughts. Future studies should investigate how learning and underlying cognitive processes are associated with perceived stress or blood pressure changes in daily life. Quite recently, Thomas et al. (2019) showed empirically that physical activity moderates the influence of daily psychosocial stressors on ambulatory blood pressure in that way, that stress-induced increases are mostly seen in people with low physical activity and not in others. This might be another reason that we did not observe an increase in blood pressure in our young and healthy sample.

Previous studies have shown influences on ambulatory blood pressure, for example, from the quality of social interaction (Cornelius et al., 2018), the type of social situation (Spitzer et al., 1992), or social conflict (Kamarck et al., 2005). As our results revealed significant differences in social contact between the two periods, we included being with another person as a control variable in our analysis. Being with others was only associated with a trend towards a higher diastolic blood pressure. However, our used control variables did show meaningful associations with blood pressure highlighting the importance of the analysis of variables that change, depending on the setting, in interpreting physiological changes.

3.2.5. Limitations

Although our results show the importance of investigating physiological processes in the context of accompanying psychological and social changes in an examination period, compared with the beginning of the semester, there are several limitations of our study. First, we did not assess perceived examination difficulty or examination mode (oral vs. written). However, there was high variance in learning time in the examination period, which suggests we did at least capture a high range of different degrees of difficulty in examinations. Second, as we allowed the students to choose the assessment week during the examination period, there might be a selection bias resultant from choosing the period leading up to a less demanding examination for the assessment procedure. If present, however, this would likely result in an underestimation of the effects found. Third, our sample consisted mainly of men studying industrial engineering in their first or third semester. There are other study subjects with more or less demanding study structures, and stress processes could also change as the students progress through university. This might limit the generalizability of our findings. However, homogeneous samples do also have advantages. To disentangle the short- and long-term consequences of stress, longitudinal studies could also explore how long after an examination period an altered CAR exists, and for whom and under which circumstances the CAR can recover. Fourth, although we tried to foster compliance by alerting the students with the smartphone every time they needed to take a cortisol sample, and by letting them write down a protocol with the timing of the cortisol samplings and additional notes of noncompliance, we cannot rule out the possibility that our results were influenced by noncompliance. However, there were no hints in the protocols and the missing values that noncompliance differed systematically between the two assessment periods. Fifth, there was a within-person effect of awakening time on S1, meaning that the later the student woke up, the higher his or her S1 was. At the between level, there was only a trend suggesting that students who wake up later have a higher S1 and a lower AUCi, but additional analysis revealed no significant differences in awakening time between the two assessment periods. Sixth, as we already had many constructs in our e-diary assessment, we did not control for location, temperature, caffeine, nicotine, and alcohol intake, or meal consumption, to avoid increasing the measurement burden. All these variables might have influenced our results. Seventh, although we controlled for activity in the analysis of blood pressure, it would also be useful to control for posture, especially postural changes. To disentangle the effect of learning on blood pressure, it would be useful to know whether it is the prolonged sitting time, the cognitive distraction, or both, that influences blood pressure.

3.2.6. Conclusion

There are significant psychological, social, and physiological changes during examination periods. Nevertheless, restorative processes, such as sleep, seem to be unaffected in our sample. Further investigation should focus on the moment-to-moment processes of psychophysiological stress, comparing periods with high background stress to periods with low background stress. Furthermore, it would be meaningful to gain more insight into the role of blood pressure and cortisol changes during attentional and cognitive learning processes, to investigate the bi-directional influences of these processes with physiological changes and psychological stress in daily life. To explore the impact of daily stress on health by examining both stressors, as well as individual resources, combining psychosocial and physiological research in everyday life is needed to deepen our understanding of the underlying processes and to design appropriate interventions.

3.2.7. References

Abouserie, R. (1994). Sources and levels of stress in relation to locus of control and self esteem in university students. *Educational Psychology*, *14*(3), 323–330.

Ahrberg, K., Dresler, M., Niedermaier, S., Steiger, A., & Genzel, L. (2012). The interaction between sleep quality and academic performance. *Journal of Psychiatric Research*, *46*(12), 1618–1622.

Bernstein, M. J., Zawadzki, M. J., Juth, V., Benfield, J. A., & Smyth, J. M. (2018). Social interactions in daily life. *Journal of Social and Personal Relationships*, *35*(3), 372–394.

Briggs, A.R.J., Clark, J., & Hall, I. (2012). Building bridges: Understanding student transition to university. *Quality in Higher Education*, *18*(1), 3–21.

Brose, A., Wichers, M., & Kuppens, P. (2017). Daily stressful experiences precede but do not succeed depressive symptoms: Results from a longitudinal experience sampling study. *Journal of Social and Clinical Psychology*, *36*(3), 196–220.

Chida, Y., & Steptoe, A. (2009). Cortisol awakening response and psychosocial factors: A systematic review and meta-analysis. *Biological Psychology*, *80*(3), 265–278.

Clow, A., Thorn, L., Evans, P., & Hucklebridge, F. (2004). The awakening cortisol response: Methodological issues and significance. *Stress*, *7*(1), 29–37.

Conley, K. M., & Lehman, B. J. (2011). Test anxiety and cardiovascular responses to daily academic stressors. *Stress and Health: Journal of the International Society for the Investigation of Stress*, *28*(1), 41–50.

Cornelius, T., Birk, J. L., Edmondson, D., & Schwartz, J. E. (2018). The joint influence of emotional reactivity and social interaction quality on cardiovascular responses to daily social interactions in working adults. *Journal of Psychosomatic Research*, *108*, 70–77.

Doerr, J. M., Ditzen, B., Strahler, J., Linnemann, A., Ziemek, J., Skoluda, N., Hoppmann, C. A., & Nater, U. M. (2015). Reciprocal relationship between acute stress and acute fatigue in everyday life in a sample of university students. *Biological Psychology*, *110*, 42–49.

Duan, H., Yuan, Y., Zhang, L., Qin, S., Zhang, K., Buchanan, T. W., & Wu, J. (2013). Chronic stress exposure decreases the cortisol awakening response in healthy young men. *Stress*, *16*(6), 630–637.

Ebner-Priemer, U. W., Welch, S. S., Grossman, P., Reisch, T., Linehan, M. M., & Bohus, M. (2007). Psychophysiological ambulatory assessment of affective dysregulation in borderline personality Disorder. *Psychiatry Research*, *150*, 265–275.

Enders, C. K., & Tofighi, D. (2007). Centering predictor variables in cross-sectional multilevel models: A new look at an old issue. *Psychological Methods*, *12*(2), 121–138.

Fahrenberg, J. (1996). Concurrent assessment of blood pressure, physical activity, and emotional state in natural settings. In J. Fahrenberg & M. Myrtek (Eds.), *Ambulatory Assessment. Computer-Assisted Psychological and Psychophysiological Methods in Monitoring and Field Studies* (pp. 165–187). Hogrefe & Huber.

Fahrenberg, J., Myrtek, M., Pawlik, K., & Perrez, M. (2007). Ambulatory Assessment - Monitoring behavior in daily life settings. *European Journal of Psychological Assessment*, *23*(4), 206–213.

Fries, E., Dettenborn, L., & Kirschbaum, C. (2009). The cortisol awakening response (CAR): Facts and future directions. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, *72*(1), 67–73.

Froehlich, J., Chen, M. Y., Consolvo, S., Harrison, B., & Landay, J. A. (2007). MyExperience: A system for in situ tracing and capturing of user feedback on mobile phones. In E. W.

Knightly, G. Borriello, & R. Cáceres (Eds.), *Proceedings of the 5th International Conference on Mobile Systems, Applications and Services - MobiSys '07* (pp. 57–70). ACM Press.

Glaser, R., Pearl, T. K., Kiecolt-Glaser, J. K., & Malarkey, W. B. (1994). Plasma cortisol levels and reactivation of latent epstein-barr virus in response to examination stress. *Psychoneuroendocrinology*, *19*(8), 765–772.

Harari, G. M., Gosling, S. D., Wang, R., Chen, F., Chen, Z., & Campbell, A. T. (2017). Patterns of behavior change in students over an academic term: A preliminary study of activity and sociability behaviors using smartphone sensing methods. *Computers in Human Behavior*, *67*, 129–138.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics*, *6*(2), 65–70.

Hughes, B. M. (2004). Academic study, college examinations, and stress: Issues in the interpretation of cardiovascular reactivity assessments with student participants. *Journal of Applied Biobehavioral Research*, *9*(1), 23–44.

Jacobs, N., Myin-Germeys, I., Derom, C., Delespaul, P., van Os, J., & Nicolson, N. A. (2007). A momentary assessment study of the relationship between affective and adrenocortical stress responses in daily life. *Biological Psychology*, *74*(1), 60–66.

Jernelöv, S., Höglund, C. O., Axelsson, J., Axén, J., Grönneberg, R., Grunewald, J., Stierna, P., & Lekander, M. (2009). Effects of examination stress on psychological responses, sleep and allergic symptoms in atopic and non-atopic students. *International Journal of Behavioral Medicine*, *16*(4), 305–310.

Juth, V., Dickerson, S. S., Zoccola, P. M., & Lam, S. (2015). Understanding the utility of emotional approach coping: Evidence from a laboratory stressor and daily life. *Anxiety, Stress, and Coping, 28* (1), 50-70.

Kamarck, T. W., Schwartz, J. E., Shiffman, S. S., Muldoon, M. F., Sutton-Tyrrell, K., & Janicki, D. L. (2005). Psychosocial stress and cardiovascular risk: What is the role of daily experience? *Journal of Personality*, *73*(6), 1749–1774.

Kudielka, B. M., Hawkley, L. C., Adam, E. K., & Cacioppo, J. T. (2007). Compliance with ambulatory saliva sampling in the Chicago health, aging, and social relations study and associations with social support. *Annals of Behavioral Medicine*, *34*(2), 209–216.

Kudielka, B. M., & Wüst, S. (2008). The cortisol awakening response (CAR): A useful tool for ambulant assessment of hypothalamus-pituitary-adrenal (HPA) axis activity. In A.-L. Léglise (Ed.), *Nova Biomedical Books. Progress in Circadian Rhythm Research* (pp. 223–234). Nova.

Kurokawa, K., Tanahashi, T., Murata, A., Akaike, Y., Katsuura, S., Nishida, K., Masuda, K., Kuwano, Y., Kawai, T., & Rokutan, K. (2011). Effects of chronic academic stress on mental state and expression of glucocorticoid receptor α and β isoforms in healthy Japanese medical students. *Stress (Amsterdam, Netherlands)*, *14*(4), 431–438.

Leary, A. C., Donnan, P. T., MacDonald, T. M., & Murphy, M. B. (2000). The influence of physical activity on the variability of ambulatory blood pressure. *American Journal of Hypertension*, *13*(10), 1067–1073.

Lovallo, W. R., Pincomb, G. A., Edwards, G. L., Brackett, D. J., & Wilson, M. F. (1986). Work pressure and the type A behavior pattern exam stress in male medical students. *Psychosomatic Medicine*, *48*(1-2), 125–133.

Malarkey, W. B., Pearl, D. K., Demers, L. M., Kiecolt-Glaser, J. K., & Glaser, R. (1995). Influence of academic stress and season on 24-hour mean concentrations of ACTH, cortisol and ß-endorphin. *Psychoneuroendocrinology*, *20*(5), 499–508.

Myin-Germeys, I., van Os, J., Schwartz, J. E., Stone, A. A., & Delespaul, P. A. (2001). Emotional reactivity to daily life stress in psychosis. *Archives of General Psychiatry*, *58*(12), 1137–1144.

Pilcher, J. J., Ginter, D. R., & Sadowsky, B. (1997). Sleep quality versus sleep quantity: Relationships between sleep and measures of health, well-being and sleepiness in college students. *Journal of Psychosomatic Research*, *42*(6), 583–596.

Powell, D. J., & Schlotz, W. (2012). Daily life stress and the cortisol awakening response: Testing the anticipation hypothesis. *PloS One*, *7*(12), e52067.

Pruessner, J. C., Kirschbaum, C., Meinlschmid, G., & Hellhammer, D. H. (2003). Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. *Psychoneuroendocrinology*, *28*(7), 916–931.

Rau, R., & Triemer, A. (2004). Overtime in relation to blood pressure and mood during work, leisure, and night time. *Social Indicators Research*, *67*(1), 51–73.

Robotham, D. (2008). Stress among higher education students: Towards a research agenda. *Higher Education*, *56*(6), 735–746.

Spangler, G., Pekrun, R., Kramer, K., & Hofman, H. (2002). Students' emotions, physiological reactions, and coping in academic exams. *Anxiety, Stress & Coping*, *15*(4), 413–432.

Spitzer, S. B., Llabre, M. M., Ironson, G. H., Gellman, M. D., & Schneiderman, N. (1992). The influence of social situations on ambulatory blood pressure. *Psychosomatic Medicine*, *54*(1), 79–86.

Stadtfeld, C., Vörös, A., Elmer, T., Boda, Z., & Raabe, I. J. (2019). Integration in emerging social networks explains academic failure and success. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(3), 792–797.

Stalder, T., Kirschbaum, C., Kudielka, B. M., Adam, E. K., Pruessner, J. C., Wüst, S., Dockray, S., Smyth, N., Evans, P., Hellhammer, D. H., Miller, R., Wetherell, M. A., Lupien, S. J., & Clow, A. (2016). Assessment of the cortisol awakening response: Expert consensus guidelines. *Psychoneuroendocrinology*, *63*, 414–432.

Stetler, C., & Miller, G. E. (2005). Blunted cortisol response to awakening in mild to moderate depression: Regulatory influences of sleep patterns and social contacts. *Journal of Abnormal Psychology*, *114*(4), 697–705.

Stone, A. A., & Shiffman, S. S. (2002). Capturing momentary, self-report data: A proposal for reporting guidelines. *Annals of Behavioral Medicine*, *24*(3), 236–243.

Tett, L., Cree, V. E., & Christie, H. (2017). From further to higher education: transition as an on-going process. *Higher Education*, *73*(3), 389–406.

Thomas, M. C., Kamarck, T. W., Li, X., Erickson, K. I., & Manuck, S. B. (2019). Physical activity moderates the effects of daily psychosocial stressors on ambulatory blood pressure. *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association*, *38*(10), 925–935.

van Someren, E. J. W., Lazeron, R. H. C., Vonk, B. F. M., Mirmiran, M., & Swaab, D. F. (1996). Gravitational artefact in frequency spectra of movement acceleration: Implications for actigraphy in young and elderly subjects. *Journal of Neuroscience Methods*, *65*(1), 55–62.

Vedhara, K., Hyde, J., Gilchrist, I. D., Tytherleigh, M., & Plummer, S. (2000). Acute stress, memory, attention and cortisol. *Psychoneuroendocrinology*, *25*(6), 535–549.

Von Haaren, B., Ottenbacher, J., Muenz, J., Neumann, R., Boes, K., & Ebner-Priemer, U. (2016). Does a 20-week aerobic exercise training program increase our capabilities to buffer real-life stressors? A randomized, controlled trial using ambulatory assessment. *European Journal of Applied Physiology*, *116*(2), 383–394.

Weik, U., & Deinzer, R. (2010). Alterations of post awakening cortisol parameters during a prolonged stress period: Results of a prospective controlled study. *Hormones and Behavior*, *58*(3), 405–409.

Wilhelm, P., & Schoebi, D. (2007). Assessing mood in daily life: Structural validity, sensitivity to change, and reliability of a short-scale to measure three basic dimensions of mood. *European Journal of Psychological Assessment*, *23*(4), 258–267.

Zhang, Z., Su, H., Peng, Q., Yang, Q., & Cheng, X. (2011). Exam anxiety induces significant blood pressure and heart rate increase in college students. *Clinical and Experimental Hypertension (New York, N.Y.: 1993)*, *33*(5), 281–286.

Zunhammer, M., Eichhammer, P., & Busch, V. (2014). Sleep quality during exam stress: The role of alcohol, caffeine and nicotine. *PloS One*, *9*(10), e109490.

3.3. Manuskript 3: Under which circumstances does academic workload lead to stress? Explaining intraindividual differences by using the cortisol-awakening response as a moderator

An adapted version of this chapter has been submitted as Koudela-Hamila, S., Santangelo, P., Ebner-Priemer, U. W., & Schlotz, W. (submitted). Under which circumstances does academic workload lead to stress? Explaining intraindividual differences by using the cortisol-awakening response as a moderator. *Journal of Psychophysiology*.

Abstract

Academic stress is associated with a wide range of adverse outcomes, including detrimental effects on mental health, achievement, and well-being. Numerous studies have shown an association of the cortisol awakening response (CAR) with various health and risk factors. Some studies revealed a protective function of the CAR as a stress buffer preventing the stress system from overshooting. We investigated the moderating effect of the CAR on the within-subject association between academic workload and the stress response in participants' daily lives using ambulatory assessment.

We assessed 77 undergraduate university participants for two days at the beginning of the semester and approximately three months later, individually starting one week before an exam. Participants provided activity-related stress and academic workload ratings hourly during their waking time using smartphone-based e-diaries and salivary cortisol samples at awakening as well as 30, 45, and 60 minutes later on two consecutive days during each of the assessment waves. Average within-subject associations between academic workload and activity-related stress were analyzed using multilevel models. Interactions with indicators of the cortisol awakening response (CAR) were included to test moderating effects of the CAR on the workload-stress associations.

There was a highly significant positive within-subject association between academic workload and the stress response. Significant cross-level interactions with cortisol indicators showed a moderating effect of the CAR on this association.

The results point out the importance of the CAR in the regulation of the workload-stress associations in academic life and underscore the relevance of investigating the influence of specific stressor dependent reciprocal effects of the CAR on learning and stress processes.

3.3.1. Introduction

Academic stress has been shown to be associated with psychological well-being, mental and physical health problems, impaired academic achievement, increased risk of dropout, substance abuse, as well as deteriorated sleep (Andrews & Wilding, 2004; Pascoe et al., 2020; Stallman, 2010; Xiang et al., 2019). Academic stress occurs when academic demands exceed the resources needed to adapt (Wilks, 2008). According to Stowell (2003), it is essential to distinguish between academic examination stress and academic stress: Whereas academic examination stress refers to stress caused directly by the examination itself (e.g., stress while writing the examination or, also, covering the time frame one hour before or after), the term academic stress should be used to characterize the stress caused by the preparation of an exam, but also by writing articles, doing homework, working in projects, or attending lectures. As our work is based on the latter, we refer to academic stress in the following.

Based on the daily life stress process model (Schlotz, 2019), academic stress can be conceptualized as a consequence of academic stressors, resulting in responses on several dimensions. Upon exposure to a stressor, e.g., a demanding learning task or high workload, appraisal processes concerning relevance, threat, and manageability of the stressor results in an individual evaluation outcome and might lead to physiological, cognitive, affective, and behavioral stress responses. For example, academic work overload might trigger increased activity of the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic-adrenal-medullary (SAM) system (physiological responses); worrying about failure, and narrowing the attentional focus on things that need to be done, while accessibility of unrelated memory items might decrease (cognitive responses: attention and memory processes); an increase in tense arousal (affective response); and drinking a beer to calm down (behavioral response). Stressors, appraisal outcomes, and stress responses can be assessed in daily life using ambulatory assessment, and stress responses in different response systems are assumed to contribute to detrimental consequences in the domains of mental and physical health. Individual differences in stress reactivity, coping, or resilience are assumed to affect the stress process at different stages.

Specifically, emotional stress reactivity has been suggested to be a risk factor for depression. This is based on observations of stronger negative affective responses to stress in individuals with current or a history of depression (Myin-Germeys et al., 2003; O'Hara et al., 2014; van Winkel et al., 2015), as well as on evidence for a prospective relationship between negative affective stress reactivity and depressive symptoms (Cohen et al., 2005; Parrish et al., 2011). Therefore, identifying factors that contribute to an attenuation of negative affective responses to daily life stress might promote individual resilience (Kalisch et al., 2017; Southwick & Charney, 2012).

It has recently been suggested that the magnitude of early morning cortisol release influences emotional stress responses later on the same day (Powell & Schlotz, 2012). One potential mechanism underlying this association is described by the cortisol boost hypotheses, which states that momentary increases in cortisol support the supply of the organism with 'energy' needed to deal with daily life demands, which then attenuates perceived stress and nervousness in everyday life (Hoyt et al., 2016).

Evidence for mood buffering effects of cortisol came from laboratory studies. First, cortisol administration was shown to lead to less negative affect after stress exposure compared to placebo administration (Het & Wolf, 2007); second, individuals with higher cortisol reactivity after a stressor showed less negative affect (Het et al., 2012; Kazén et al., 2012); and third, high levels of cortisol were associated with low levels of anxiety 5-10 minutes later (Schlotz et al., 2008). Hoyt et al. (2016) tested the cortisol boost hypothesis in a daily electronic diary study and found momentary increases in cortisol to be associated with subsequent increases in activeness, alertness, and relaxation, and trend-level decrease in stress and nervousness. Increases in 'energy', activeness and alertness could also affect the stress process during varying levels of workload due to increased 'energy' to cope with the demands of the day.

However, these studies investigated momentary increases in cortisol. The CAR is associated with HPA Axis activity and physiological changes around the process of awakening (Clow et al., 2010). It is thought to provide 'energy' to deal with the demands of the day in that it permits and prepares physiological processes needed later on during the day (Schulz et al., 1998). Therefore, a higher CAR might serve a protective stress-buffering function. In an electronic diary study, Powell and Schlotz (2012) investigated day-specific stress regulatory effects of the CAR. Higher CAR increases and lower first cortisol samples after awakening were associated with attenuated momentary distress in association with daily life stress, suggesting a stress-buffering function of the CAR that helps an individual to deal with the demands in everyday life. Therefore, studies are needed which test the buffer-hypothesis investigating the CAR as a moderator of the demand-distress relationship. Although the effect of the CAR increase after awakening was day-specific in the study of Powell and Schlotz (2012), the effect of the first cortisol sample after awakening was not, which suggests that for different CAR indicators, different levels of analysis, and consequently, the separation of within- and between-subjects variance, might be important and necessary.

Depending on different behaviors needed with specific stressors to overcome a challenging situation, different types of stressors could lead to varying consequences regarding psychological and physiological changes (Keay & Bandler, 2001). When investigating the CAR respective to the specific stressor of high academic workload, the CAR might influence the stress process in different ways. First, the CAR might affect memory function and executive processes. There are studies suggesting a link between the CAR and hippocampal memory functions (e.g., Almela et al., 2012; Rimmele et al., 2010) and prefrontal structures with executive function (Law et al., 2020). A study by Ennis et al. (2016) showed an association of the CAR on episodic memory and of the waking cortisol levels on working memory. If morning cortisol changes, so that memory function is impaired, learning could become more burdensome, and therefore, the stress response could increase.

Moreover, a second speculative way of the CAR in indirectly influencing cognitive processing could be through the already above mentioned decreased emotional stress response. For example, Henckens et al. (2010) showed that exogenous administration of cortisol normalized the emotional response to negative stimuli by altering prefrontal control of the amygdala. Normalization may be particularly important in the context of studying because studies show that cognitive performance is worse if emotional stimuli activate affective responses (e.g., Dolcos & McCarthy, 2006).

Psychophysiological studies investigating stress responses with different physiological variables suggest that physiological stress responses are affected by the existence of background stress, with inconsistent findings regarding the direction of influence on the stress response - some found higher reactivity, though others found lower reactivity in the presence of background stress (see Gump & Matthews, 1999 for a review). In the context of academic workload, proximity to an examination period might change the level of background stress, and this could change the association between academic workload and academic stress.

Furthermore, it is unclear if background stress changes not only the stress response but also the functionality of the physiological stress system, which could lead to a difference in the stress-buffering function of the CAR during an examination period compared to a less stressful period at the beginning of the semester. In the context of exam stress, several studies showed a change in the magnitude of CAR indices during an examination period (Duan et al., 2013; Koudela-Hamila et al., 2020). Additionally, findings by Hewig et al. (2008) suggest bidirectional influences of cortical asymmetry and cortisol secretion during a period of academic examinations, suggesting changes in the functioning of the physiological system during the existence of background stress.

It is essential to distinguish between different levels of analysis regarding CAR measures, as studies have shown high situational variability (Hellhammer et al., 2007; Ross et al., 2014) and day-specific effects of the CAR (Powell & Schlotz, 2012). To be able to separate between- from within-person effects and to investigate psychophysiological stress-processes with high ecological validity, we used ambulatory assessment techniques. Ambulatory assessment is characterized by multiple assessments per person per day over a certain period, investigating antecedents and consequences of psychological and/or physiological variables in real-time in everyday life, thereby avoiding recall bias and enabling the investigation of within-person changes in daily life (Schlotz, 2019; Trull & Ebner-Priemer, 2014). Psychological data in everyday life is usually assessed with smartphones, with the advantage of separating within from between-person variance, investigating within-person processes, in real-time, in real life, and the possibility of time-stamping the data entries to circumvent backfilling (Stone et al., 2002).

We are interested in the stressor-stress relationship, as cortisol might not only buffer the stress response but also, at an earlier step in the stress process model, the perception of being stressed. The appraisal of being stressed through the perception of work overload might be influenced by the estimation of having enough energy to cope with the situation. As noted earlier, studies suggest that the CAR might give the body the '*energy*' needed to deal with the demands of daily life (Schulz et al., 1998) and so could lead to an appraisal of being better able to manage the situation (Engle-Friedman et al., 2008; Schafer & McKanna, 1991). As time spent studying is an indicator of student academic workload that might lead to academic stress in students, and academic stress is associated with critical educational goals such as academic achievement and dropout rates, we investigated the association between workload as a stressor and the subjective reports of academic activity related stress in students' daily life using ambulatory assessment. Accordingly, as our first hypothesis, we examined if there is a positive within-subject association between workload —operationalized as time spent studying— and activity-related academic stress. We chose to test the CAR as a moderator of academic stress, as evidence showed that the CAR could be an essential resilience factor that supports the attenuation of negative affective stress responses (Powell & Schlotz, 2012). Therefore, in our second hypothesis, we hypothesize a stress-buffering function of the CAR. Since studies show that the stress process is influenced by background stress (see Gump & Matthews, 1999 for a review), we collected data at two different assessment waves: one week at the beginning of the semester, when there are no deadlines and workload is relatively low, and exactly one week before an examination, when the workload is high due to time pressure (Koudela-Hamila et al., 2019). As a result of background stress, we assume in our third hypothesis, a different association between workload and activity-related stress between the two assessment waves. Additionally, in our fourth hypothesis, we examine if there is a difference in the moderating role of the CAR depending on the presence or absence of background stress at the two different assessment waves.

3.3.2. Methods

Study Design

Data was collected once at the beginning of the semester (assessment wave 1) and once at the examination period, exactly one week before an examination (assessment wave 2). We used ambulatory assessment to capture the daily life experience of the participants. During both assessment waves, participants carried a smartphone, which functioned as an e-diary and emitted a beep every full hour during the whole waking time of the participants for one week at both assessment waves. Participants collected saliva samples on the first two days of the study week to determine the cortisol awakening response. We used the smartphone data of these two days at each assessment wave to test our hypotheses.

Participants were asked to take part in the study if they were enrolled in courses that were preselected for practical reasons (such as courses that were primarily attended by students in their first and third semesters). They were informed about the study, started the e-diary, received instructions on the collection of saliva, and were handed over the eight saliva collection devices (Salivettes) needed for the two-day cortisol sampling. After this first study week, the participants returned all devices and Salivettes. Later in the semester, they informed the research team about their examination dates, which served as a basis to make individual appointments for the second assessment wave precisely one week before an exam. Devices and Salivettes of this assessment wave were returned after the examination. To facilitate compliance, we offered an individualized report about data provided by each participant, including a personal coaching session on how to deal with the individually most relevant stressors. All participants provided written informed consent. Ethical approval for our study was not mandatory, according to local and national law.

Participants

N = 77 students took part in this study. Most of the participants were male (n = 56, 73%) and studying '*industrial engineering and management*' (n = 68, 88%). The mean age of all participants was 20.9 years (SD = 1.1). Most of the participants were in their first or third semester (n = 61, 79%), and 75 (97%) of the participants had German nationality. Four participants (5%) took oral contraceptives.

Measurements: Cortisol

The saliva samples were collected by participants using cortisol Salivettes (Sarstedt; Rommelsdorf, Germany). Following current guidelines (Stalder et al., 2016), participants collected a saliva sample immediately after awakening (S1), 30 minutes, 45 minutes, and 60 minutes later. Participants were instructed not to eat, brush their teeth, smoke, or engage in any physical exercise, and to drink nothing but water until the cortisol assessments were finished on that morning. To ensure compliance, the smartphone presented a random three-digit code each time saliva should be collected, which the participants had to write on the label of the Salivette tube they were currently using (cf. Powell & Schlotz, 2012). Participants were instructed to store used Salivettes in their refrigerator until the end of the study-week. After having been returned to the laboratory, samples were stored at -20°C. Samples were sent in one batch to the Biochemical Laboratory at the Division of Theoretical and Clinical Psychobiology, University of Trier, Germany, and were analyzed for cortisol concentrations (nmol/L) by time-resolved immunoassay with fluorescence detection (Dressendorfer et al., 1992). The detection limit for the assay was 0.173 nmol/L. Each sample was measured in duplicate, with an intra-assay coefficient of variance between 4.0% and 6.7%, and an inter-assay coefficient of variance between 7.1% and 9.0%. We used the mean value of two measurements of a sample for our analysis.

Two participants dropped out at the second assessment wave, and three participants did not return any of their Salivettes. At the first assessment wave, data from one day of one participant had to be excluded entirely from the analysis due to markedly delayed saliva sampling resulting from waking up early. Additionally, we excluded one participant-day at the second assessment wave because the participant did eat before taking the samples, and sampling times were outside of the predefined criteria. We excluded one unrealistically high cortisol measurement (S1 = 60 nmol/L), and two samples were missing due to lost Salivettes. Additionally, we excluded all cortisol samples that were taken outside a range of +/- 5 minutes around their scheduled sampling time. We used sensitivity analyses to test whether four participants with unusually variable, high, or low cortisol concentrations substantially affected the results of our analyses. As this was not the case, we included this data in the results of the statistical analyses at hand.

Cortisol at awakening: Two different components were derived following current guidelines (Stalder et al., 2016), namely the cortisol level upon awakening (S1) and the area under the curve with respect to increase (AUCi), which indicates the dynamic of change.

Measurements: E-Diary Data

Participants started the e-diary on the handheld computer as they woke up and put the e-diary in sleep mode before going to bed. The handheld computer emitted a signal every full hour (9:00 a.m., 10:00 a.m., 11:00 a.m., etc.) during the waking hours of each assessment day. We chose a non-random sampling scheme and allowed for a maximum response delay of ten-minutes to improve the accuracy of time use estimations. If a participant did not answer within this period, data from that assessment was recorded as missing. All responses were time-stamped automatically. Smartphones (HTC Touch Diamond II, Windows Mobile 6.5) were programmed using the e-diary software MyExperience Movisens Edition (Movisens GmbH, Karlsruhe, Germany; Froehlich et al., 2007). Due to technical issues, smartphone data from one participant at assessment wave one, and from two other participants at assessment wave two, could not be used.

Academic workload: We used the following ten different categories to classify time use: “courses” (e.g., lectures, workshops, tutorials), “learning-oriented activities” (e.g., reading relevant literature, thesis work, presentation preparation, literature research, explaining things to other students), “other academic activities” (e.g., borrowing books from the library, printing documents, organizing something at the study office), “transport and idle time”, “housework, eating, and body care”, “job”, “active leisure time” (e.g., sport, social contacts), “passive leisure time” (e.g., watching television, playing on the computer), “sleeping”, and “other activities”. This classification allowed the participants to proportionally allocate the 60 minutes (plus 10 in case of delayed response) of their actual time use to these ten categories. In our sample, the mean values over all assessments per hour (averaged over the two assessment waves) were 5 minutes for courses, 13 minutes for learning, 1 minute for other academic activities, 4 minutes of transport and idle time, 8 minutes for housework, eating and body care, 1 minute for working at a job, 8 minutes active leisure time, 13 minutes passive leisure time, 1 minute sleep, and 1 minute other activities. In this paper, we only used the first two categories, courses and learning. To get a time estimate of participant academic workload, we summed up these two categories, because they constitute the two main categories of student work activities.

Momentary activity-related stress: To assess the stressfulness of the academic work, participants answered at each prompt the following four items of activity-related stress: *I'm not skilled to do this activity; I would rather do something else; this activity requires effort; the tasks are too much for me right now (scale 1-7).* The first three items of this scale were used in multiple e-diary studies by Myin-Germeys (e.g., 2001). We added the last item to include excessive demands in the stress assessment. To get an overall estimate of participants' momentary stress, the mean of these four items was calculated for each hourly assessment.

Data Analyses

To accurately model the nested data structure and deal with missing data that is common in ambulatory assessment studies, we used multilevel regression models with a three-level structure to analyze the potential moderating role of cortisol indices of awakening on the association between academic workload and momentary activity-related stress of participants. Regarding the hierarchical data structure, measurement occasions (level 1) were nested in days (level 2), which were nested in participants (level 3). The outcome variable was activity-related stress. We included activity-related stress at the previous assessment (i.e., t-1) as a within-subject predictor variable to capture the effect of studying on stress change since the previous assessment. At level 3 (i.e., the person-level), we adjusted the model for age, use of oral contraceptives, and gender, and at level 2 (i.e., the day-level) for time of awakening and assessment wave. Two hierarchical models were analyzed, one using S1 and one using AUCi as CAR-related predictors of activity-related stress. The units of the cortisol at awakening indices were converted from nmol/L into µmol/L to avoid parameters with many leading decimal zeros. To test the hypothesized moderator effect of the cortisol indices on the workload-stress association (i.e., the stress-buffering function), we included the cross-level interaction of workload with the respective cortisol indicator (S1 or AUCi) in the model. To test for expected differences between the two different assessment waves in the within-person association of workload with activity-related stress, as stated in the third hypothesis, we included the cross-level interaction of workload with assessment wave in the model. As we hypothesized a difference in the moderator function of the cortisol at awakening on the workload-stress association depending on the assessment wave, we included the three-way cross-level interaction of workload with assessment wave and cortisol at awakening in the model.

Full maximum likelihood estimation was used for all models. To reduce model complexity and because we had only four days of cortisol assessment, we did not include random effects for slopes at level 3 in the model. Additionally, we removed the random effect of the intercept of the lagged stress variable at level 3, as likelihood ratio tests indicated that it did not significantly contribute to the model.

Within- and between-subject effects were separated by centering all predictor variables at levels 1 and 2 within clusters at their level-specific mean (Enders & Tofighi, 2007). In addition, participants' age was grand-mean centered. Categorical predictors were coded as follows: Assessment wave (-0.5 = assessment wave one, 0.5 = assessment wave two); use of oral contraceptives (0 = no, 1 = yes); gender (0 = male, 1 = female).

Data management was done using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). Statistical analyses of the multilevel models and deviance tests were performed using HLM version 7.03 (Raudenbush & Bryk, 2002). An alpha level of $p < .05$ was used for all statistical analyses.

3.3.3. Results

As hypothesized, academic workload showed a significant positive effect on activity-related stress in both models ($p < .001$), which is listed, together with all other multilevel analysis findings, in the level 1-section of Table 1. This denotes that the more the participants studied, the higher were their self-reported levels of activity-related stress. In addition, there was a significant cross-level interaction effect of S1 ($p < .001$), as well as AUCi ($p = .025$), with time spent studying on activity-related stress (hypothesis 2). On days with a higher S1 or lower AUCi, individuals showed a less strong association of academic workload with activity-related stress than on days with lower S1 or higher AUCi (see Figure 1). The cross-level interaction of assessment wave with academic workload was significant both for S1 ($p = .016$) and AUCi ($p = .029$), indicating that the association between academic workload and activity-related stress was stronger in the examination period (hypothesis 3). Testing hypothesis 4, there was no significant three-way interaction between cortisol at awakening, assessment wave, and academic workload on perceived stress, neither for S1 ($p = .750$) nor for AUCi ($p = .223$). This means that there were no significant differences in the effect of the cortisol at awakening on the workload-stress association regarding the two assessment waves.

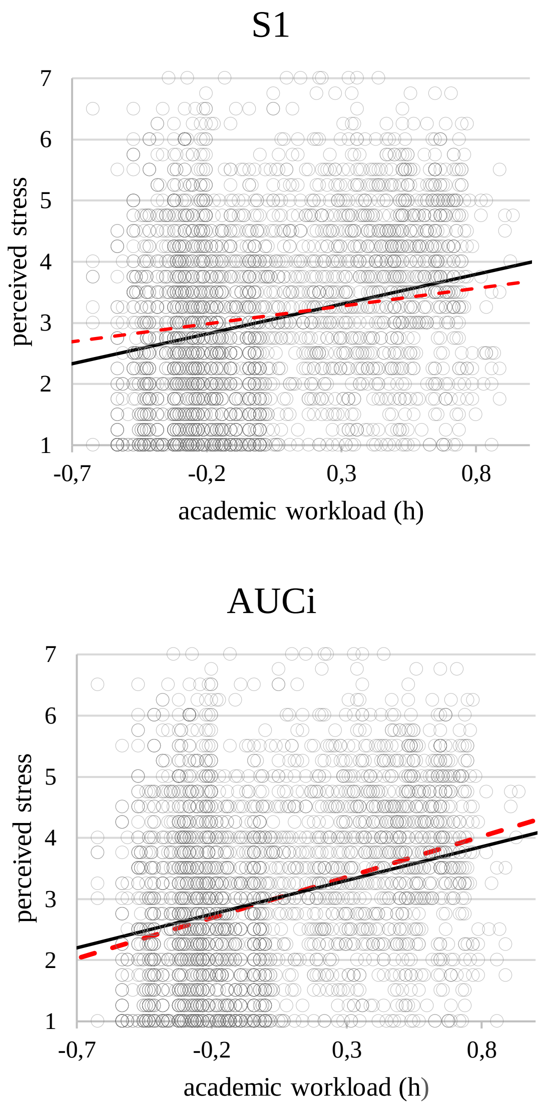


Figure 1. Attenuated (S1) and strengthened (AUCi) academic workload (within-subject centered)-stress association. The dashed line marks one SD above the average of S1/AUCi, and the solid line marks one SD below the average of S1/AUCi.

Table 1. Results from the Multilevel Analysis predicting activity-related stress from academic workload, cortisol at awakening and assessment wave (-0.5 = assessment wave one, 0.5 = assessment wave two), controlling for age, oral contraceptives (0 = no, 1= yes), gender (0 = male, 1 = female), time of awakening, and activity-related stress at the preceding assessment.

Criterion: activity-related stress	S1			AUCi		
Predictors:	*β (SE)*	*t*	*p*	*β (SE)*	*t*	*p*
Intercept	2.98** (0.13)	22.24	<.001	2.97** (0.14)	22.05	<.001
Level 3						
Age	0.07 (0.10)	0.70	.483	0.07 (0.10)	0.72	.473
Oral contraceptives	-0.21 (0.40)	-0.51	.609	-0.23 (0.41)	-0.56	.579
Gender	0.02 (0.27)	0.09	.930	0.04 (0.27)	0.14	.888
Level 2						
Time of awakening	-0.05 (0.06)	-0.92	.362	-0.05 (0.05)	-0.83	.408
Cortisol after awakening	8.87 (14.94)	0.59	.554	-0.03 (0.30)	-0.11	.913
Assessment wave	0.34* (0.14)	2.47	.016	0.35* (0.14)	2.52	.014
Assessment wave x cortisol after awakening	-11.78 (26.84)	-0.44	.662	0.10 (0.55)	0.19	.854
Level 1						
Stress at (t-1)	0.16** (0.02)	6.83	<.001	0.16** (0.02)	6.79	<.001
Academic workload (in hours)	1.13** (0.09)	12.29	<.001	1.16** (0.09)	12.82	<.001
Assessment wave x academic workload	0.29* (0.12)	2.46	.016	0.27* (0.12)	2.22	.029
Cortisol after awakening x academic workload	-40.92** (10.29)	-3.98	<.001	0.47* (0.20)	2.28	.025
Assessment wave x cortisol after awakening x academic workload	-11.92 (37.33)	-0.32	.750	0.88 (0.72)	1.23	.223

3.3.4. Discussion

As expected, we found a significant effect of academic workload on activity-related stress, and a stress-buffering function of the CAR increase (AUCi) and the first cortisol value after awakening (S1). On days where the CAR increase (AUCi) was less pronounced, and the first value after awakening (S1) was higher, a less strong association between academic workload and perceived stress could be shown. We found a higher association between academic workload and activity-related stress the week before an exam. No differences between the cortisol buffering-function were found for the two assessment waves.

The moderation effects of the CAR increase (AUCi), as well as the first value after awakening (S1), were not entirely in line with the results of Powell and Schlotz (2012), which can be explained by the different designs used. Powell and Schlotz (2012) found an attenuated distress stress response on days with a higher CAR increase (AUCi) and a lower first value after awakening (S1). However, there are some differences in the variables used between the two studies. In contrast to Powell & Schlotz (2012), we used academic workload instead of perceived stress as a predictor and perceived activity-related stress instead of distress as a criterion. Although not being the same variables, there should be a high association between them. However, academic workload is no social stressor, and it is linked to processes of learning, like attention and memory processes. The hippocampus is thought to play an essential role in memory processes and also to be related to HPA-Axis regulatory functions (e.g., Pruessner et al., 2007). Additionally, influences of cortisol on learning and cognitive processing have been documented in the literature (e.g., Lupien et al., 2005; Vogel & Schwabe, 2016). Ennis et al. (2016) revealed a better working memory function on days with higher cortisol waking levels. However, there are inconsistent results on the association between cortisol indices, stress, and memory function (Ennis et al., 2016; Lewis et al., 2008). Lupien et al. (2005) discuss differences in the effect of cortisol depending on the phase of learning like acquisition, consolidation or retrieval, emotionality vs. neutrality of the stimulus learned, as well as an inverted u-shaped association between memory processes and the cortisol level to account for the different results obtained in various studies. A study by Hewig et al. (2008) found different cortisol increases and cortisol levels at awakening in an exam period to be associated with different lateralized cortical activation. According to the results of these studies, one could consider a flatter increase after awakening to be functional regarding the situation of studying, and so leading to less perceived stress. However, further studies are needed to test these assumptions.

The association of academic workload with activity-related stress was more pronounced in the period of the exam preparation, as the results showed a positive cross-level interaction effect of the assessment wave with academic workload. Regarding background stress, inconsistent findings exist in the literature (Gump & Matthews, 1999). Our results point out to sensitization effects indicated by a higher workload-stress association in the examination period. As our sample consisted of students mainly in their first or third semester, participants probably had not much experience with exams in a university setting, so sensitization was more likely to occur than habituation. Another difference regarding the two assessment waves may be the amount of time pressure, which could influence the workload – stress association (Teuchmann et al., 1999). Although it could also be present at the beginning of the semester, as papers and presentations have deadlines as well, it should be more prevalent in the exam period.

Even though we found a higher stress response in the period of the exam preparation, no significant interaction of the assessment wave with the buffer function of the CAR was found. It seems as if only the magnitude of the CAR changes, leaving the functionality in the stress regulation of the CAR unchanged. However, we only assessed the CAR on four days, two times per assessment wave, so our power to detect a differential effect of assessment wave might be limited. Nevertheless, on a descriptive level, it seems that the buffer-function of the

CAR changes as individual stress levels increase, as the regression lines of S1 and AUCi, one standard deviation under and above the mean, cross in the middle of the individual-centered stress scales (see Figure 1).

Although we were the first reporting an influence of the cortisol awakening response on academic stress using daily-life real-time characterizations of workload and stress within a reasonable sample size, we have to report some limitations. First, the shape of the cortisol awakening response could also be influenced by the compliance of the participants (Stalder et al., 2016). The participants documented the time of taking the saliva samples as well as any behavior that was not in accordance with the study protocol. However, we cannot rule out the possibility of non-compliance, as our study missed an objective verification of awakening time. Second, previous analysis of our data showed that the increase after awakening and the first value after awakening changes significantly comparing the beginning of the semester with the exam period (Koudela-Hamila et al., 2020). However, we controlled for assessment waves in the analysis, and the interaction effects of the CAR indices with academic workload remained significant. Third, our sample was mainly male. There are studies showing gender differences in the shape of the CAR and the stress response (Brougham et al., 2009; Merz & Wolf, 2017; Weekes et al., 2008). However, we controlled for gender in our analysis and found no significant gender differences in the stress level.

3.3.5. Conclusion

We were able to reveal a protective stress-buffering function of the CAR in real life using ambulatory assessment. We investigated activity-related stress in the context of academic workload as a specific stressor. Changes in the magnitude of the CAR may be dependent on the cognitive processes needed in the situation of studying – e.g., attention, recall of information, or working memory. The CAR might influence the workload – stress association directly, but also indirectly by influencing the processes associated with learning, thereby affecting learning performance and leading to more or less stressful appraisals of the academic situation.

3.3.6. References

Almela, M., van der Meij, L., Hidalgo, V., Villada, C., & Salvador, A. (2012). The cortisol awakening response and memory performance in older men and women. *Psychoneuroendocrinology*, *37*(12), 1929–1940.

Andrews, B., & Wilding, J. M. (2004). The relation of depression and anxiety to life-stress and achievement in students. *British Journal of Psychology* (95), 509–521.

Brougham, R. R., Zail, C. M., Mendoza, C. M., & Miller, J. R. (2009). Stress, Sex Differences, and Coping Strategies Among College Students. *Current Psychology*, *28*(2), 85–97.

Clow, A., Hucklebridge, F., Stalder, T., Evans, P., & Thorn, L. (2010). The cortisol awakening response: more than a measure of HPA axis function. *Neuroscience & Biobehavioral Reviews*, *35*(1), 97–103.

Cohen, L. H., Gunthert, K. C., Butler, A. C., O'Neill, S. C., & Tolpin, L. H. (2005). Daily affective reactivity as a prospective predictor of depressive symptoms. *Journal of Personality*, *73*(6).

Dolcos, F., & McCarthy, G. (2006). Brain systems mediating cognitive interference by emotional distraction. *The Journal of Neuroscience*, *26*(7), 2072–2079.

Dressendorfer, R. A., Kirschbaum, C., Rohde, W., Stahl, F., & Strasburger, C. J. (1992). Synthesis of a cortisol-biotin conjugate and evaluation as a tracer in an immunoassay for salivary cortisol measurement. *Journal of Steroid Biochemistry and Molecular Biology*, *43*, 683–692.

Duan, H., Yuan, Y., Zhang, L., Qin, S., Zhang, K., Buchanan, T. W., & Wu, J. (2013). Chronic stress exposure decreases the cortisol awakening response in healthy young men. *Stress*, *16*(6), 630–637.

Enders, C. K., & Tofighi, D. (2007). Centering predictor variables in cross-sectional multilevel models: A new look at an old issue. *Psychological Methods*, *12*(2), 121–138.

Engle-Friedman, M., Riela, S., & Strothers, E. (2008). Objective and subjective effort as a function of sleep and energy. *Sleep and Hypnosis*, *10*(2), 61–72.

Ennis, G. E., Moffat, S. D., & Hertzog, C. (2016). The cortisol awakening response and cognition across the adult lifespan. *Brain and cognition*, *105*, 66–77.

Froehlich, J., Chen, M. Y., Consolvo, S., Harrison, B., & Landay, J. A. (2007). MyExperience: A system for in situ tracing and capturing of user feedback on mobile phones. In E. W. Knightly, G. Borriello & R. Cáceres (Hg.), *Proceedings of the 5th international conference on mobile systems, applications and services - MobiSys ‘07* (S. 57–70). ACM Press.

Gump, B. B., & Matthews, K. A. (1999). Do background stressors influence reactivity to and recovery from acute stressors? *Journal of Applied Social Psychology*, *29*(3), 469–494.

Hellhammer, J., Fries, E., Schweisthal, O. W., Schlotz, W., Stone, A. A., & Hagemann, D. (2007). Several daily measurements are necessary to reliably assess the cortisol rise after awakening: state- and trait components. *Psychoneuroendocrinology*, *32*(1), 80–86.

Henckens, M. J. A. G., van Wingen, G. A., Joëls, M., & Fernández, G. (2010). Time-dependent effects of corticosteroids on human amygdala processing. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *30*(38), 12725–12732.

Het, S., Schoofs, D., Rohleder, N., & Wolf, O. T. (2012). Stress-induced cortisol level elevations are associated with reduced negative affect after stress: Indications for a mood-buffering cortisol effect. *Psychosomatic Medicine*, *74*(1), 23–32.

Het, S., & Wolf, O. T. (2007). Mood changes in response to psychosocial stress in healthy young women: Effects of pretreatment with cortisol. *Behavioral Neuroscience*, *121*(1), 11–20.

Hewig, J., Schlotz, W., Gerhards, F., Breitenstein, C., Lürken, A., & Naumann, E. (2008). Associations of the cortisol awakening response (CAR) with cortical activation asymmetry during the course of an exam stress period. *Psychoneuroendocrinology*, *33*(1), 83–91.

Hoyt, L. T., Zeiders, K. H., Ehrlich, K. B. & Adam, E. K. (2016). Positive upshots of cortisol in everyday life. *Emotion (Washington, DC)*, *16*(4), 431–435.

Kalisch, R., Baker, D. G., Basten, U., Boks, M. P., Bonanno, G. A., Brummelman, E., …& Kleim, B. (2017). The resilience framework as a strategy to combat stress-related disorders. *Nature Human Behaviour*, *1*(11), 784–790.

Kazén, M., Kuenne, T., Frankenberg, H., & Quirin, M. (2012). Inverse relation between cortisol and anger and their relation to performance and explicit memory. *Biological Psychology*, *91*(1), 28–35.

Keay, K. A., & Bandler, R. (2001). Parallel circuits mediating distinct emotional coping reactions to different types of stress. *Neuroscience & Biobehavioral Reviews*, *25*(7-8), 669–678.

Koudela-Hamila, S., Grund, A., Santangelo, P., & Ebner-Priemer, U. W. (2019). Valence and motivation as predictors of student time use in everyday life: An experience sampling study. *Frontiers in Psychology*, *10*: 1430.

Koudela-Hamila, S., Smyth, J., Santangelo, P., & Ebner-Priemer, U. (2020). Examination stress in academic students: A multimodal, real-time, real-life investigation of reported stress, social contact, blood pressure, and cortisol. *Journal of American College Health*.

Law, R., Evans, P., Thorn, L., Hucklebridge, F., Loveday, C., & Clow, A. (2020). The cortisol awakening response predicts a same-day index of executive function in healthy young adults. *International Journal of Psychophysiology*, *158*, 27-33.

Lewis, R. S., Nikolova, A., Chang, D. J., & Weekes, N. Y. (2008). Examination stress and components of working memory. *Stress (Amsterdam, Netherlands)*, *11*(2), 108–114.

Lupien, S. J., Buss, C., Schramek, T. E., Maheu, F., & Pruessner, J. (2005). Hormetic influence of glucocorticoids on human memory. *Nonlinearity in Biology, Toxicology, Medicine*, *3*(1), 23–56.

Merz, C. J., & Wolf, O. T. (2017). Sex differences in stress effects on emotional learning. *Journal of Neuroscience Research*, *95*(1-2), 93–105.

Myin-Germeys, I., Peeters, F., Havermans, R., Nicolson, N. A., Vries, M. W., Delespaul, P. A., & van Os, J. (2003). Emotional reactivity to daily life stress in psychosis and affective disorder: An experience sampling study. *Acta Psychiatrica Scandinavica*, *107*(2), 124–131.

Myin-Germeys, I., van Os, J., Schwartz, J. E., Stone, A. A., & Delespaul, P. A. (2001). Emotional reactivity to daily life stress in psychosis. *Archives of General Psychiatry*, *58*(12), 1137–1144.

O'Hara, R. E., Armeli, S., Boynton, M. H., & Tennen, H. (2014). Emotional stress-reactivity and positive affect among college students: The role of depression history. *Emotion (Washington, DC)*, *14*(1), 193–202.

Parrish, B. P., Cohen, L. H., & Laurenceau, J. P. (2011). Prospective relationship between negative affective reactivity to daily stress and depressive symptoms. *Journal of Social and Clinical Psychology*, *30*(3), 270–296.

Pascoe, M. C., Hetrick, S. E., & Parker, A. G. (2020). The impact of stress on students in secondary school and higher education. *International Journal of Adolescence and Youth*, *25*(1), 104–112.

Powell, D. J., & Schlotz, W. (2012). Daily life stress and the cortisol awakening response: Testing the anticipation hypothesis. *PloS One*, *7*(12), e52067.

Pruessner, M., Pruessner, J. C., Hellhammer, D. H., Bruce Pike, G., & Lupien, S. J. (2007). The associations among hippocampal volume, cortisol reactivity, and memory performance in healthy young men. *Psychiatry Research*, *155*(1), 1–10.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2. Ed.). *Advanced quantitative techniques in the social sciences: Vol. 1*. SAGE Publications.

Rimmele, U., Meier, F., Lange, T., & Born, J. (2010). Suppressing the morning rise in cortisol impairs free recall. *Learning & Memory (Cold Spring Harbor, NY), 17*(4), 186–190.

Ross, K. M., Murphy, M. L. M., Adam, E. K., Chen, E., & Miller, G. E. (2014). How stable are diurnal cortisol activity indices in healthy individuals? Evidence from three multi-wave studies. *Psychoneuroendocrinology*, *39*, 184–193.

Schafer, W. E., & McKanna, J. F. (1991). Perceived energy and stress resistance: A study of city managers. *Journal of Social Behavior and Personality*, *6*(2), 271–282.

Schlotz, W. (2019). Investigating associations between momentary stress and cortisol in daily life: What have we learned so far? *Psychoneuroendocrinology*, *105*, 105–116.

Schlotz, W., Kumsta, R., Layes, I., Entringer, S., Jones, A., & Wüst, S. (2008). Covariance between psychological and endocrine responses to pharmacological challenge and psychosocial stress: A question of timing. *Psychosomatic Medicine, 70*(7), 787–796.

Schulz, P., Kirschbaum, C., Pruessner, J., & Hellhammer, D. (1998). Increased free cortisol secretion after awakening in chronically stressed individuals due to work overload. *Stress Medicine, 14*, 91–97.

Southwick, S. M., & Charney, D. S. (2012). The science of resilience: Implications for the prevention and treatment of depression. *Science (New York, N.Y.)*, *338*(6103), 79–82.

Stalder, T., Kirschbaum, C., Kudielka, B. M., Adam, E. K., Pruessner, J. C., Wüst, S., …, & Clow, A. (2016). Assessment of the cortisol awakening response: Expert consensus guidelines. *Psychoneuroendocrinology*, *63*, 414–432.

Stallman, H. M. (2010). Psychological distress in university students: A comparison with general population data. *Australian Psychologist*, *45*(4), 249–257.

Stone, A. A., Shiffman, S. S., Schwartz, J. E., Broderick, J. E., & Hufford, M. R. (2002). Patient non-compliance with paper diaries. *British Medical Journal*, *324*(7347), 1193–1194.

Stowell, J. R. (2003). Use and abuse of academic examinations in stress research. *Psychosomatic Medicine*, *65*(6), 1055–1057.

Teuchmann, K., Totterdell, P., & Parker, S. K. (1999). Rushed, unhappy, and drained: An experience sampling study of relations between time pressure, perceived control, mood, and emotional exhaustion in a group of accountants. *Journal of Occupational Health Psychology*, *4*(1), 37–54.

Trull, T. J., & Ebner-Priemer, U. (2014). The role of ambulatory assessment in psychological science. *Current Directions in Psychological Science*, *23*(6), 466–470.

Van Winkel, M., Nicolson, N. A., Wichers, M., Viechtbauer, W., Myin-Germeys, I., & Peeters, F. (2015). Daily life stress reactivity in remitted versus non-remitted depressed individuals. *European Psychiatry: The Journal of the Association of European Psychiatrists*, *30*(4), 441–447.

Vogel, S., & Schwabe, L. (2016). Learning and memory under stress: Implications for the classroom. *NPJ science of learning*, *1*, 16011.

Weekes, N. Y., Lewis, R. S., Goto, S. G., Garrison-Jakel, J., Patel, F., & Lupien, S. (2008). The effect of an environmental stressor on gender differences on the awakening cortisol response. *Psychoneuroendocrinology*, *33*(6), 766–772.

Wilks, S. E. (2008). Resilience amid academic stress: The moderating impact of social support among social work students. *Advances in Social Work, 9*(2), 106–125.

Xiang, Z., Tan, S., Kang, Q., Zhang, B., & Zhu, L. (2019). Longitudinal effects of examination stress on psychological well-being and a possible mediating role of self-esteem in Chinese high school students. *Journal of Happiness Studies*, *20*(1), 283–305.

4. ABSCHLIESSENDE DISKUSSION UND AUSBLICK

Ziel dieser Arbeit war es Workload und Stress von Studierenden zu erfassen. Workload wurde im Alltag in Echtzeit erfasst. Es wurde Wert darauf gelegt Stress multimodal und ebenfalls im Alltag von Studierenden zu erfassen, um auf möglichst breiter Ebene Veränderungen in einer Prüfungsphase zu dokumentieren und das komplexe Geschehen im Alltag von Studierenden möglichst genau abzubilden. Somit können in einem nächsten Schritt wechselseitige Zusammenhänge analysiert werden.

Zunächst werden die Ergebnisse der drei Manuskripte, insbesondere bezüglich weiterer Forschungsansätze, diskutiert. Danach folgt als Ausblick die Darstellung dreier Forschungsthemen, die in weiteren Forschungsarbeiten vertieft werden sollten.

4.1. Manuskript 1: Valence and motivation as predictors of student time use in everyday life: An experience sampling study

Zusammenfassend lässt sich festhalten, dass Studierende am KIT in der untersuchten Stichprobe den von Bologna vorgegebenen Workload von 40 Stunden pro Woche im Schnitt erfüllen. Es gibt allerdings eine hohe Streuung, die in weiteren Studien analysiert werden sollte. Wichtig wäre zu wissen welche Eigenschaften die beiden Extremgruppen und die Studierenden im Mittelfeld der Verteilung haben. Vermutet werden kann, dass Konzepte, wie z.B. Perfektionismus und Prokrastinationstendenzen, hier eine Rolle spielen. Die hohe Varianz des Workloads konnte in den vorliegenden Analysen durch Stimmung und Motivation, sowie in der Prüfungsphase durch Unterschiede in der sozialen Unterstützung zumindest zum Teil erklärt werden. Diese Ergebnisse können im Sinne der Selbstbestimmungstheorie von Deci und Ryan (1993) interpretiert werden. Da in der Selbstbestimmungstheorie soziale Unterstützung zu einem höheren Durchhaltevermögen beiträgt und soziale Unterstützung in den Ergebnissen mit der Lernzeit korreliert war, wären die Ergebnisse, was die Befunde zur sozialen Unterstützung anbelangt, in Einklang mit der Theorie. Allerdings ist unklar warum soziale

Unterstützung gerade in der Prüfungsphase relevant ist. Hier wäre denkbar, dass sich Studierende in ihrer Motivation zum Lernen unterstützen. Die Motivationsprozesse, die in diesen Lernprozess eingebunden sind, sollten in weiteren Studien genauer beleuchtet werden. Hierbei könnten die Dimensionen extrinsische und intrinsische Motivation in die Erfassung miteinbezogen werden, da sie wichtige Bezüge zum Stresskonzept enthalten (Deci & Ryan, 1993). Intrinsisch motiviertes Verhalten bezeichnet interessensbestimmte Handlungen, der keine Belohnungen oder Bestrafungen folgen. Extrinsisch motiviertes Verhalten wird durch bestimmte Konsequenzen motiviert, also mit instrumenteller Absicht durchgeführt. Intrinsische und extrinsische Motivation sind aber keine Gegensatzpaare. Es gibt Formen der extrinsischen Motivation, die der intrinsischen sehr ähnlich sind, da Werte und Normen integriert wurden (Deci & Ryan, 1993) und so ein recht hohes Maß an Selbstbestimmung gegeben ist. In verschiedenen Studien konnte ein Zusammenhang zwischen Selbstbestimmung und Lernqualität sowie Schulabbruch aufgezeigt werden (siehe Deci & Ryan, 1993 für einen Überblick). Änderungen der Studienstruktur, die dem Lerner mehr Autonomie einräumen, könnten den Anteil an Selbstverantwortung stärken und eventuell die intrinsische Motivation fördern.

Ein weiterer Einflussfaktor auf den Workload könnte die Angst vor Misserfolg (Vermeidungsverhalten) vs. die Hoffnung auf Erfolg (aufsuchendes Verhalten) sein. Sobald sich die Studierenden mit dem Prüfungsstoff auseinandersetzen wird die Angst vor Misserfolg in besonderem Maße aktiviert, sodass Prokrastination bzw. Vermeidungsverhalten wahrscheinlicher werden. Sowohl die Angst vor Misserfolg, als auch die Hoffnung auf Erfolg, könnten tageszeitlichen oder themenbezogenen Schwankungen unterworfen sein. Die Erfassung von Lern- und Freizeit, zusammen mit diesen Konstrukten im Alltag von Studierenden, sowie die emotionalen, kognitiven und physiologischen Folgen, könnten wichtige Einblicke in die selbstregulatorischen Prozesse im universitären Lernsetting geben.

Auch langfristige Folgen könnten untersucht werden, um die Bedeutung dieser Prozesse für die berufliche Zukunft genauer beurteilen zu können. Die Befunde könnten wichtige Informationen zur Entwicklung von Interventionen liefern.

In der vorliegenden Arbeit wurde erfasst ob zu einem gegebenen Zeitpunkt andere Personen anwesend waren. Dies sagt aber nichts darüber aus wie unterstützend dieser Sozialkontakt war oder welchem Zweck er gedient hat. Zur Häufigkeit von Sozialkontakten könnte zusätzlich noch die Qualität von Sozialkontakten erfasst werden – d.h. wie unterstützend werden diese wahrgenommen und welche Formen von Coping werden dabei unterstützt (z.B. problemorientiertes, emotionsorientiertes oder vermeidendes Coping; Carver et al., 1989). Interessant wäre weiterhin die Auswirkung unterschiedlicher Qualitäten von Sozialkontakten auf Affektveränderungen – d.h. wie hängen Ausgangsemotion, die Art der sozialen Unterstützung und Folgeemotion zusammen.

Aus datenschutzrechtlichen Gründen konnten keine Noten der Studierenden erfasst werden. Dies wäre sicherlich informativ im Sinne der Effizienzbeurteilung der mit Lernen verbrachten Zeit. Ebenso wichtig wären Langzeitstudien, die einen Bezug zum wichtigen Thema Studienabbruch, erreichter Studienabschluss, psychische und physische Gesundheit und Workload herstellen. Weiterhin zeigte sich, dass auch beim Lernen Stimmungsveränderungen im negativen Sinne erfolgen. Studien, die die Funktionalität dieser Veränderungen untersuchen, wären von Nutzen. Man könnte hier mutmaßen, dass die negative Stimmung gebraucht wird, im Sinne eines schlechten Gewissens, um mit dem Lernen zu beginnen und somit das schlechte Gewissen zu beruhigen. Dies wäre ein motivationaler Ansatz: Die Motivation einen unerwünschten Zustand zu beenden bildet den Ausgangszustand, um mit dem Lernen zu beginnen. Gasper und Spencer (2018) beschreiben in ihrem Überblicksartikel den Einfluss von Affekt auf kognitive Prozesse, auf den unter 4.4.2. noch ausführlicher eingegangen wird. Verschiedene Studien legen nahe, dass unter positivem Affekt mehr kognitive Heuristiken und mehr globale Verarbeitungsstrategien eingesetzt werden und demnach unter negativem Affekt die Feinheiten und konkreten Dinge mehr Beachtung finden und systematischer an Themen herangegangen wird (siehe Gasper & Spencer, 2018, für einen Überblick). Diese Befunde legen nahe, dass es funktional sein könnte beim Lernen schlechte Stimmung zu haben.

Weiterhin wäre es wichtig die verbrachte Zeit nicht, wie in der vorliegenden Arbeit geschehen, über eine Stunde kumulativ zu untersuchen, sondern die Probanden die Kategorien auf einem Zeitstrahl über die letzte Stunde eintragen zu lassen. Somit ließen sich Zeitmuster untersuchen, so z.B. ob Pausen gemacht wurden, wann diese stattfanden und welche kurz- und langfristigen Konsequenzen sich daraus auf emotionaler, kognitiver, sozialer, physiologischer und Verhaltensebene ergeben. Durch die Analyse der Zeitmuster und deren Konsequenzen könnte die Funktionalität des Zeitmanagements der Studierenden bewertet werden. Zur Bewertung der Funktionalität des Zeitmanagements könnten unterschiedliche Faktoren herangezogen werden. Einmal das Lernergebnis oder die Lerneffizienz (Lernen pro Zeit, oder subjektive Einschätzung der Lerneffizienz), aber auch die unmittelbaren kognitiven (Aufmerksamkeit, Konzentrationsfähigkeit, Arbeitsgedächtniskapazität), affektiven und physiologischen Folgen (Blutdruck und Cortisol). Zudem könnten die langfristigen Folgen in Bezug auf physiologische Marker, emotionale oder kognitive Leistungen (z.B. Gedächtnis, Konzentration) unmittelbar nach der Prüfungszeit und ein paar Wochen danach, in Bezug zu den Lernzeitmustern und dem Stress in der Prüfungsphase gesetzt werden.

Die Kategorien, passive und aktive Freizeitgestaltung, sollten in weiteren Studien genauer differenziert werden. Vor allem Beschäftigungen vor dem Computer, Tablet oder Smartphone wären genauer auf die beiden Kategorien zu verteilen bzw. in eigenen Kategorien zu bewerten. Filme oder Serien anzuschauen, Musikvideos zu betrachten, chatten, alleine oder in Gemeinschaft Videospiele spielen – das alles könnte unterschiedliche Auswirkungen auf das

Stressempfinden, die Stimmung, das Arbeitsgedächtnis, die Konzentration und den Workload haben.

4.2. Manuskript 2: Examination stress in academic students: a multimodal, real-time, real-life investigation of reported stress, social contact, blood pressure, and cortisol

Ein weiteres wichtiges Ergebnis ist, dass das Stressniveau von Studierenden im Schnitt im mittleren Bereich lag. Allerdings gab es eine hohe Varianz, d.h. es gab Studierende, die im oberen Bereich, als auch im unteren Bereich der verwendeten Skalen lagen. In diesem Zusammenhang wäre es sinnvoll sich Extremgruppen von Studierenden genauer anzuschauen, wie z.B. Studierende, die viel lernen und wenig gestresst sind, oder solche, die wenig lernen und stark gestresst sind und deren Merkmale zu analysieren.

Vergleicht man den Beginn des Semesters mit der Prüfungsphase weisen die Ergebnisse darauf hin, dass die Regenerationsfähigkeit der Studierenden vermutlich noch erhalten geblieben ist. Unterschiede im Energieniveau, in der Schlafqualität oder in der Blutdrucknachtabsenkung konnten in dieser Studie nicht beobachtet werden. Der systolische Blutdruck war sogar niedriger in der Prüfungsphase als zu Beginn des Semesters. Das könnte am vermehrten Lernen in der Prüfungsphase liegen, welches häufig im Sitzen geschieht. Zwar wurde in dieser Studie Aktivität miterhoben – allerdings fehlte die Information zu Veränderungen der Lage, da nur ein Sensor an der Brust getragen wurde und somit nicht zwischen Stehen und Sitzen unterschieden werden kann. In weiteren Studien sollte darauf geachtet werden einen zusätzlichen Aktivitätssensor am Oberschenkel anzubringen, um Sitzen von Stehen unterscheiden zu können. Weiterhin fehlen Untersuchungen im Bereich von Blutdruck und Lernen im Alltag von Studierenden. Es könnte durchaus sein, dass das Stressniveau absinkt, weil die Studierenden von ihren ruminativen Gedanken abgelenkt sind, da sie sich komplett auf das Lernen konzentrieren und somit der Blutdruck sinkt, weil die Anspannung zurückgeht.

Auch die CAR veränderte sich in der Prüfungsphase verglichen mit dem Beginn des Semesters. Der erhöhte Aufwachwert in der Prüfungsphase könnte eine adaptive Reaktion im Sinne einer Vorbereitung auf die Anstrengungen des Tages sein (Powell & Schlotz, 2012). Der abgeflachte Morgenanstieg könnte mit Lernprozessen in Verbindung stehen (Kazén et al., 2012). Auch hier wären weitere Studien angezeigt, die den Zusammenhang zwischen Lernen und CAR näher betrachten und im Hinblick auf die Lernqualität oder auch Lerneffizienz genauer untersuchen.

Die vorliegende Auswertung zeigt auf, dass es wichtig ist sich die Gesamtheit der Faktoren, die sich in einer Prüfungsphase verändern im Vergleich zum Beginn des Semesters, genau anzusehen. In weiteren Analysen könnte der Zusammenhang zwischen den sich veränderten Faktoren, wie z.B. dem Sozialkontakt und den Stressvariablen oder auch der Blutdrucknachtabsenkung genauer betrachtet werden. Die Ergebnisse von Gramer et al. (2003) weisen darauf hin, dass die Reaktivität des diastolischen Blutdrucks auf akademischen Stress, z.B. vor allem durch die Anwesenheit eines bewertenden Beobachters, entstehen könnte.

Im Hinblick auf die Veränderungen, die sich vor und nach einer Prüfung auf sozialer, psychischer und physiologischer Ebene vollziehen, wären Längsschnittstudien mit mehreren Erhebungen vor und nach einer Prüfung sinnvoll, sogenannte *Measurement-Burst-Designs* – Phasen von zeitlich getrennten Erhebungen mittels Ambulantem Assessment (Ram & Gerstorf, 2009). So könnte man z.B. erkennen, wie lange es braucht bis die CAR wieder in einen Zustand, ähnlich dem zu Beginn des Semesters, zurückkehrt, für wen und unter welchen Umständen dies eventuell nicht geschieht, und ob sich die CAR im Verlauf des Studiums bei einigen Personen ändert, sowie ob dies in Zusammenhang mit psychischen Prozessen oder auch dem Entstehen psychischer Störungen stehen könnte und welche Faktoren protektiv wirken.

Um mehr Power in den Multilevelmodellen zu gewährleisten, wäre es in weiteren Studien sinnvoll Blutdruck über mehrere Tage zu erfassen. Dabei sollte der Anfangstag variiert werden, um mögliche Wochentags Effekte abbilden zu können. Auch könnte der Abstand zur Prüfung variiert werden und zusätzlich nach der Prüfung erhoben werden, um mögliche Regenerationsprozesse abbilden zu können.

4.3. Manuskript 3: Under which circumstances does academic workload lead to stress? Explaining intraindividual differences by using the cortisol-awakening response as a moderator

Wichtig für die Erforschung von Stressprozessen und die Entstehung psychischer und körperlicher Krankheiten durch stressreiche Ereignisse, ist es herauszufinden unter welchen Umständen bzw. mit Hilfe welcher Ressourcen Personen nach stressigen Ereignissen nicht krank werden. Dies ist Teil der Resilienzforschung und wird von Kalisch et al. (2017) definiert als die Beibehaltung oder schnelle Erholung der geistigen Gesundheit während oder nach dem Auftreten eines signifikanten Stressors. Resilienz resultiert aus einem dynamischen Prozess der Adaption an stressreiche Lebensumstände. Kalisch et al. (2017) betonen, dass noch zu wenig im Bereich der Stressprävention getan wird. Hierbei wäre es wichtig zu wissen, welche Faktoren oder Prozesse im Sinne einer Resilienz hilfreich sind, um diese in Trainings stärken zu können. Kalisch et al. (2017) lehnen Resilienzforschung aus der *trait*-Perspektive ab, da diese bereits durch die Forschung zur Vulnerabilität ausreichend abgedeckt sei. Wichtiger sei eine Prozessperspektive einzunehmen, die vor, während und nach Auftreten eines stressreichen Ereignisses, Prozesse aufdeckt, die dazu führen, dass eine Person nur kurzfristig auf diesen Stressor reagiert und nicht langfristig negative Konsequenzen erlebt. Zusätzlich sei es wichtig genauer den Kontext und den Stressor zu spezifizieren sowie die Intensität des Stressors zu bestimmen, um abschätzen zu können, ob die Stressor-Outcome Beziehung durch die untersuchten Resilienz-Prozesse moderiert wird. Kalisch et al. (2017) betonen auch die

Notwendigkeit einer multimodalen Erfassung der Stressprozesse. In weiteren Studien mit Studierenden könnte die Datenerhebung auf Zeitpunkte vor, während und nach der Prüfung ausgeweitet werden. Darüber, wie schnell jemand zum Ausgangsstresswert psychologisch oder physiologisch zurückkehrt, könnten Klassifizierungen resilienter Personen vorgenommen werden. Die Intensität des Stressors müsste über die Prüfungsschwierigkeit eingeschätzt werden. Verschiedene Coping-Prozesse (Carver et al., 1989; soziale, kognitive, emotionale, physiologische Prozesse) könnten erfasst und ihre Bedeutung als Resilienz-Prozesse bestimmt werden. Auswirkungen der Art des Copings (z.B. emotions- vs. problemfokussiert) auf physiologische Parameter, wie den Blutdruck oder die CAR, wären ebenfalls im Sinne einer die Resilienz fördernden Faktoren interessant. Weiterhin wäre es auch wichtig die Art und Intensität des Stressors zu bestimmen, um mögliche Unterschiede in der Funktionalität verschiedener Coping-Formen miteinbeziehen zu können. Ambulantes Assessment würde sich als Methode zur multimodalen Bestimmung solcher Prozesse im Alltag besonders eignen, da mehrmals, in einen gewissen Zeitraum, Daten erhoben werden und somit dynamische sozio-psychische sowie physiologische Prozesse im Fokus stehen.

Dass die CAR vermutlich ein wichtiger Moderator im Umgang mit Stress ist, zeigen die Ergebnisse der dritten Studie. Die Stressbewertung nach dem Studieren war geringer mit hohem Cortisol-Aufwachwert (S1) und niedrigem Cortisolanstieg (AUCi). Unterschiede in den Ergebnissen im Vergleich zu der Studie von Powell & Schlotz (2012) können aufgrund unterschiedlicher Stresserfassungsmerkmale und unterschiedlichem Fokus auf den Stressentstehungsprozess entstanden sein. Die Analysen zur CAR sind ein Beispiel für die Betrachtung des komplexen Wechselspiels von psychischen und physiologischen Prozessen, sowie protektiver, die Resilienz fördernder Prozesse im Stressentstehungsprozess.

Für die Analyse der mittelfristigen Veränderungen, im Sinne von Resilienz- bzw. Erholungs-Prozessen, sollte in mehreren Erhebungswellen vor während und nach der Prüfung erfasst werden, aber auch über eine längere Dauer von mindestens vier bis fünf Tagen, um mögliche Unterschiede der CAR Moderationseffekte zwischen Beginn des Semesters und Prüfungswoche entdecken zu können. Weiterhin sollten die Probanden einen Aktivitätssensor tragen, nicht nur um die Aufstehzeit valide zu bestimmen (Smith et al., 2020), sondern auch um eine evtl. protektive Wirkung von Bewegung auf hormonelle Prozesse im Alltag aufzeigen zu können (Adolphs et al., 1997; Hill et al., 2008; Puterman et al., 2011).

4.4. Ausblick

Drei Forschungsansätze für weitere Studien werden im Folgenden noch einmal ausführlicher dargestellt. Bevor damit begonnen wird, soll aber zunächst kurz auf die Unterscheidung zwischen Stimmung, Emotion und Affekt eingegangen werden, da diese Konzepte in den vorgestellten Forschungsansätzen Anwendung finden. Im Bereich der Emotionsforschung gibt es große Unterschiede und Uneinigkeit hinsichtlich der Gültigkeit in der Begriffszuordnung und den zugrunde gelegten Theorien (z.B. Batson et al., 1992; Ekman, P., & Davidson, R. J., 1994; Russell, 2003). In Übereinstimmung mit Batson et al. (1992) definieren wir Stimmung und Emotionen als affektive Zustände. Während angenommen wird, dass Stimmung sich langsam verändert und durch viele verschiedene Ursachen beeinflusst und verändert werden kann, wird angenommen, dass Emotionen nach der Bewertung von spezifischen Ereignissen auftreten und intensivere, eher kurzfristige Affektveränderungen bewirken. Im Gegensatz zur Stimmung entsteht bei dem Auftreten einer Emotion eine für diese Emotion charakteristische Veränderung der einzelnen Subsysteme (Verhalten und Ausdruck, Kognition, Motivation, Physiologie), eine Unterbrechung des bisherigen Verhaltens und eine Ausrichtung des Handelns auf ein bestimmtes Ziel. Diese Unterscheidung von Affekt, Stimmung und Emotion sei als Arbeitsdefinition zu verstehen – ob die Unterscheidung tatsächlich nicht nur ein Produkt unseres Sprachgebrauchs ist, sondern auch durch Studien belegt werden kann, muss weitere Forschung zeigen (Beedie et al., 2005).

Der erste Forschungsansatz betrachtet Stress aus der Perspektive der Forschung im Bereich von Emotionen. Für die Anwendung im Ambulanten Assessment kann dies von hohem Nutzen sein, da Emotionen ein Konglomerat aus vielen verschiedenen Merkmalen des Kontextes bilden. Der Kontext, in dem ein Verhalten im Alltag stattfindet, ist komplex. Die Erfassung von Emotionen bildet einen Ansatz, der diese Komplexität zusammengefasst abbildet und gleichzeitig einen engen Bezug zu physiologischen Konstrukten beinhaltet. Diese Art der Verkürzung ist praktikabel und zusätzlich differenzierter als die Erfassung der Stressbewertung alleine und könnte insbesondere hinsichtlich der physiologischen Folgen von Vorteil sein.

Der zweite Ansatz bezieht sich auf den Zusammenhang zwischen Affekt und kognitiven Prozessen. Dieser konnte in unterschiedlichen Studien belegt werden (Gasper & Spencer, 2018). Nicht nur beeinflussen Bewertungen nachfolgenden Affekt – auch Affekte beeinflussen die nachfolgende Verarbeitung einer Situation. Die Studien, die es hierzu gibt, sind nahezu ausschließlich Laborstudien. Ob gleiches auch im Kontext des Alltags Gültigkeit besitzt, gilt es zu klären. Die oftmals vertretene Ansicht, dass Lernen Spaß mache, sollte in weiteren Studien auf ihren Wahrheitsgehalt und ihre Funktionalität hin überprüft werden.

Die Ergebnisse der vorliegenden Arbeit zeigen zudem die Besonderheit der psychophysiologischen Zusammenhänge während Lernprozessen, die bisher nur in wenigen Studien, meist im Labor, betrachtet wurden. Der dritte Ansatz beschäftigt sich mit den Zusammenhängen von physiologischen Vorgängen in Verbindung mit kognitiven Lern- und Aufmerksamkeitsprozessen. Denkbar wäre, dass die Physiologie einen Einfluss auf kognitive Maße besitzt, und dass es, z.B. durch Veränderungen aufgrund von Prüfungsangst oder Lernstress, zu physiologischen Veränderungen kommt, die das Lernen erschweren, indem Lern- und Aufmerksamkeitsprozesse gestört werden. Im Studienalltag könnten diese Prozesse mit hoher ökologischer Validität mittels Ambulantem Assessment untersucht werden.

4.4.1. Emotionen im erweiterten Stresskonzept

Insbesondere bei der Untersuchung von Stress stellt sich die Frage, wie Stress definiert wird, da unterschiedlichen Theorien dazu existieren (Karasek, 1979; Lazarus, R.S., Folkman, S., 1984; McEwen, 1998; Schlotz, 2019). Emotionen werden im Modell von Schlotz (2019) als Reaktionen auf Stress beschrieben. Sie können ein wichtiges Bindeglied zwischen Stresswahrnehmung und physiologischen Reaktionen bilden. Es gibt eine Vielzahl an Komponenten, die die Stressentstehung beeinflussen, wie z.B. unterschiedliche Art an Stressoren, unterschiedliche Erfahrungen mit Situationen, soziale Situationen vs. aufgabenbezogene Situationen oder auch Ressourcen einer Person, die die weitere Stressverarbeitung entscheidend beeinflussen und sich in ihren Folgen unterscheiden können. Ein komplexes Zusammenspiel unterschiedlichster Kontextfaktoren und innerpsychischer Prozesse bestimmen die Stressentstehung und weitere Verarbeitung.

Lazarus plädiert in seinem 1993 erschienen Artikel dafür (Lazarus, 1993), Emotionen einen zentralen Stellenwert in der Stressforschung einzuräumen. Er sieht Emotionen nicht nur als Reaktion auf einen Stressor, sondern nimmt an, dass andere Emotionen auch zu anderen Stressqualitäten führen. Auf diese kognitiv-motivational-relationale Theorie der Emotionen (*cognitiv-motivational-relational theory of emotions*) von Lazarus (1993) wird im Folgenden näher eingegangen. Emotionen spiegeln die Beziehungen einer Person mit ihrer Umwelt wider und hängen gleichzeitig mit der Bedeutsamkeit der Situation für die Person und den gelernten Adaptionsmechanismen zusammen. Emotionen entstehen dann, wenn die Person ein Ziel hat, also motiviert ist. Sie unterscheiden sich auch danach, ob es um die Person selbst geht oder um die Auseinandersetzung mit einer anderen Person. Dem Ausdruck unterschiedlicher Emotionen liegen somit unterschiedliche Motive und unterschiedliche soziale und situationale Beziehungen zu Grunde. Emotionen können aus vielen einzelnen Kognitionen entstehen, die der Person nicht bewusst sein müssen und damit schwer erfassbar sein können. Emotionen entstehen somit nach Lazarus (1993) nach einer gewissen Logik der Motivation, Bewertung und Interaktionserfahrung, die eine Person besitzt. Jeder Emotion liegt ein bestimmtes Bewertungs- und Motivationsmuster zu Grunde. Emotionen fassen all das zusammen und differenzieren gleichzeitig, aufgrund der bei der Entstehung unterschiedlicher Kontextbedingungen und Bewertungen, zwischen verschiedenen Erregungszuständen bzw. Erregungsqualitäten. Mit der Häufigkeit und Intensität, mit der eine Emotion erlebt wird, könnten unterschiedliche positive oder negative physiologische Konsequenzen verbunden sein. Auch könnte, über die Häufigkeit und Intensität der Emotionen im Alltag, im Schnitt eine Einschätzung über deren Funktionalität vorgenommen werden. In Einzelfällen kann es beispielsweise sinnvoll sein, häufiger mit Wut zu reagieren, um bestimmte Dinge durchzusetzen. Im Mittel über viele Personen sollte dies aber nicht funktional sein und mit möglicherweise negativen physiologischen Veränderungen einhergehen.

Lazarus (1993) befürwortet den Einbezug von Emotionen auch in der Erforschung des Coping-Prozesses. Auch Coping sei von dem motivationalen Bezug der Person-Umwelt-Beziehung, die den Emotionen zugrunde liegen, beeinflusst. Ob eine Person in einer Situation mit Wut oder Angst reagiert, beeinflusst auch die weitere Auswahl an Reaktionen auf die Situation. Neben Absichten und generellen Zielen seien die Emotionen von zentraler Bedeutung, nicht nur für die Qualität des Stresses, sondern auch für die weitere Verarbeitung.

Die funktionelle Perspektive von Stress nimmt genau diese Überlegungen zu Emotionen auf und wird bei Moons et al. (2010) beschrieben. Sie verbindet Emotionen mit den physiologischen Reaktionen im Stressprozess. Sie nimmt an, dass unterschiedliche Emotionen mit unterschiedlichen Bewertungen, unterschiedlichem Verhalten und unterschiedlichen physiologischen Prozessen verbunden sind. Wut ist z.B. mit der Bewertung von Sicherheit, geringem Risiko und Überlegenheit verbunden, was wiederum zu konfrontativem Verhalten führt. Angst dagegen mit der Bewertung von Unsicherheit, Risiko und Unterlegenheit und einer

Tendenz, zu vermeiden und sich zurückzuziehen. Emotionen stellen hierbei das Mittel dar mit dem Stressreaktionen an spezifische Stressoren angepasst werden. Von dem Stressor und den zugrundeliegenden Erfahrungen einer Person wird somit eine bestimmte Emotion ausgelöst, welche physiologische Prozesse beinhaltet, die z.B. eine *fight*- oder *flight*- Reaktion unterstützen. Die vermehrte Ausschüttung von Cortisol z.B., liefert dem Organismus Energie und hemmt proinflammatorische Prozesse, was wiederum mit einer besseren Wundheilung einhergeht (Moons et al., 2010). Auch Trauer und positive Emotionen wären als Reaktion denkbar, was wiederum mit anderen Bewertungen, Verhaltenskonsequenzen und physiologischen Prozessen assoziiert sein könnte. Studien legen nahe, dass verschiedene Emotionen wie Angst, Scham oder Wut, unterschiedliche Auswirkungen auf die Cortisolausschüttung und den Cortisolspiegel haben. Während bei Angst und Scham ein Anstieg des momentanen Cortisols gezeigt werden konnte, wurde im Zusammenhang mit Wut bzw. Ärger eine verringerte Cortisolausschüttung in Studien aufgezeigt (Herrero et al., 2010; Kazén et al., 2012; Matheson & Anisman, 2009; Moons et al., 2010). Diese Unterschiede in den physiologischen Prozessen zwischen verschiedenen Emotionen betonen die Notwendigkeit, bei der Untersuchung physiologischer Stressprozesse, der ausgelösten Emotion eine zentrale Stellung einzuräumen. Auch die langfristigen körperlichen Folgen könnten sich mit der jeweils ausgelösten Emotion unterscheiden, da über die Zeit in unterschiedlicher Häufigkeit bestimmte physiologische Prozesse ausgelöst werden. Im Lernkontext wären vor allem die Emotionen, Angst, Ärger und Scham, aber auch die Zustände Langeweile und Überforderung zu unterscheiden. Zusätzlich könnten Konflikte in anderen Bereichen und das Auftreten von Freude, im Sinne von Ressourcen oder weiteren Hintergrundstressoren, das Lernen beeinflussen. Wenn Emotionen einen zentralen Stellenwert im Stressprozess einnehmen so könnte auch der Miteinbezug von Emotionen in (präventiven) Stresstrainings sinnvoll sein. Spezielle Interventionen für Studierende mit bestimmten Emotionstendenzen könnten angeboten werden, welche dann eventuell auch der Prävention bestimmter körperlicher und psychischer Erkrankungen dienen könnten. E-Diaries können zudem in Interventionen eingesetzt werden, um zu Beginn einen Überblick über das momentane Stressniveau, Zeiteinteilung, Stressoren und beteiligte emotionale Prozesse zu erhalten. Zum Abschluss des Seminars kann über E-Diaries überprüft werden, inwieweit die gelernten Strategien bereits zu einer Veränderung der Stressverarbeitung im Alltag geführt haben.

4.4.2. Affekt und kognitive Informationsverarbeitung

Schlechte Stimmung ging in den Ergebnissen des ersten Manuskripts mit mehr Lernen einher, und je mehr gelernt wurde, desto mehr verschlechterte sich die Stimmung der Studierenden. Es stellt sich nun die Frage, ob diese schlechte Stimmung lernen eher behindert oder fördert. Zahlreiche Befunde (siehe Gasper & Spencer, 2018 für einen Überblick) zeigen den Einfluss von Affekt auf die Informationsverarbeitung und auch die Informationsbewertung. Frühe Theorien über den Zusammenhang von Affekt und kognitiver Verarbeitung gingen davon aus, dass Affekte die mentale Kapazität verringern. Dies konnte in Studien aber nicht bestätigt werden (Gasper & Hackenbracht, 2015; Yang et al., 2013). Vielmehr konnte gezeigt werden, dass positive Affekte mit einer vermehrten Nutzung abstrakter/globaler Strategien verbunden sind – die *top down* Verarbeitung somit dominiert. Unter negativem Affekt kam es dagegen verstärkt zu konkreter, detaillierterer Informationsverarbeitung – im Sinne einer *bottom up* Verarbeitung (Burger & Bless, 2016; Curby et al., 2012; Johnson et al., 2010). Allerdings scheinen weitere Faktoren zusätzlich zum Affekt, wie die motivationale Intensität bzw. die Zielorientierung, auch eine Rolle zu spielen, welche Art der Informationsverarbeitung stattfindet. Es wird angenommen, dass geringe motivationale Intensität mit globalen Strategien einhergeht, während hohe motivationale Intensität mit detaillierten Strategien verbunden ist (Gable & Harmon-Jones, 2010). Einen weiteren Hinweis zur Auswirkung von Affekt auf die Informationsverarbeitung zeigen Studien, in denen gefunden wurde, dass positiver Affekt mit einer verstärkten Nutzung von kognitiven Heuristiken verbunden ist und somit weniger anhand der aktuellen Informationen entschieden wird (Forgas, 2011; Greifeneder & Bless, 2008). Studien zeigen zudem, dass Kreativität ebenfalls von der Affektqualität beeinflusst wird (z.B. Davis, 2009 für einen Überblick). Allerdings zeigen Studien auch, dass es bei der Untersuchung der Auswirkungen von negativem Affekt auf Kreativität wichtig ist zwischen negativen Affekten zu differenzieren, da es hier scheinbar zu Unterschieden in der Informationsverarbeitung kommen kann (Gasper & Spencer, 2018). Wenn nun Lernen mit negativem Affekt verbunden ist, könnte dies nach obigem Erkenntnisstand funktional sein, wenn es für das Bestehen der Prüfung wichtig ist, konkrete detaillierte Informationen gelernt zu haben.

Oftmals wird in einer Situation nicht nur eine Affektqualität, im Sinne von unterschiedlichen Emotionen, aktiviert, sondern viele. Wie diese Emotionen zusammenspielen und welche Auswirkungen dies auf die Verarbeitungsprozesse hat, wäre in weiteren Studien zu untersuchen. Gerade beim Lernen könnte es durch Zielkonflikte zu ambivalenten Emotionen kommen. Bei welchen Studierenden diese auftreten und wie diese im Alltag gelöst werden, wäre insbesondere für die Gestaltung von zielgerichteten Interventionen sinnvoll zu wissen.

Das Zusammenspiel von *trait* und *state* Affekt und kognitiven Prozessen im Alltag von Studierenden, könnte weiterhin analysiert werden. Verarbeiten, z.B. Studierende mit hohen Neurotizismuswerten (*trait-Ebene*), Informationen anders als Studierende mit niedrigen Werten, wenn diese in positiver/negativer Stimmung sind? Das Wissen um diese Zusammenhänge könnte ebenfalls genutzt werden, um Interventionen zur Lerngestaltung optimaler auf einzelne Studierendengruppen zuzuschneiden.

Die dargestellten Zusammenhänge von Affekt und Strategien der Informationsverarbeitung beruhen zum großen Teil auf Laborstudien, in denen bestimmte Affekte gezielt ausgelöst wurden. Eine Überprüfung, unter Verwendung von Ambulantem

Assessment unter Alltagsbedingungen könnte klären, ob die Befunde auch für natürlich auftretende Affekte Gültigkeit haben.

4.4.3. Cortisol, Blutdruck und kognitive Leistung

Es gibt nur wenige Arbeiten, die sich mit den physiologischen Veränderungen während des Lernens auseinandersetzen. Dabei macht es durchaus Sinn zu fragen, welche physiologischen Vorgänge den Lernprozess unterstützen bzw. begleiten und wie diese beeinflusst werden können. Länger andauernde Stressphasen können physiologische Veränderungen bewirken, die wiederum auf Lernprozesse einwirken. In Studien konnten sowohl Zusammenhänge von Cortisol mit kognitiver Leistung (Almela et al., 2012; Ennis et al., 2016) als auch von krankhaften Veränderungen des Blutdrucks mit kognitiven Defiziten gefunden werden (Novak & Hajjar, 2010; Power et al., 2013). Auf die möglichen physiologischen Veränderungen von Cortisol und Blutdruck im Lernkontext und deren Auswirkungen auf kognitive Prozesse soll im Folgenden eingegangen werden.

Die physiologischen Regelkreise der CAR legen nahe, dass es aufgrund der Regulation der CAR durch den Hypocampus Zusammenhänge zu kognitiven Funktionen geben könnte. Jedoch existieren hierzu nur wenige Studien, die zudem den Zusammenhang im Labor untersuchen. Die vorhandenen Studien weisen darauf hin, dass für die kognitive Leistung ein mittleres Maß an Cortisolausschüttung, kongruent mit den Aussagen bzgl. des Erregungsoptimums für das Lernen nach dem Yerkes-Dodson-Gesetz, optimal sein könnte (Kloet et al., 1999). Die Ergebnisse einer Studie von Almela et al. (2012) beispielsweise legen einen quadratischen Zusammenhang zwischen der CAR und Verfahren zur Messung deklarativer Gedächtnisprozesse nahe. Es konnte in der gleichen Studie ein positiver Zusammenhang der CAR mit dem Arbeitsgedächtnis gezeigt werden, jedoch nur für Männer. Die Probanden in der Studie waren allerdings zwischen 55 und 77 Jahre alt. Eine Studie von Ennis et al. (2016) konnte einen positiven Zusammenhang zwischen der CAR und dem

Arbeitsgedächtnis, unabhängig vom Alter der Probanden, zeigen. Das Alter der Studienteilnehmer war breiter gestreut als in der Almela et al. (2012) Studie – sie waren zwischen 23 und 79 Jahre. Schilling et al. (2013) berichten über einen umgekehrt U-förmigen Zusammenhang zwischen Cortisol, was intravenös verabreicht wurde, und der Erinnerungsleistung in einem Gedächtnistest. Die Befunde legen nahe, dass nicht nur die CAR Zusammenhänge zu kognitiven Prozessen im Alltag zeigt, sondern auch unmittelbare Cortisol Anstiege im Alltag mit der Veränderung von kognitiven Funktionen zusammenhängen könnten. Zusammenhänge von Cortisol mit kognitiven Prozessen könnten untersucht werden, indem nicht nur die CAR im Alltag, sondern auch momentanes Cortisol zusammen mit Tests zur Konzentration und zur Arbeitsgedächtniskapazität ambulant mittels Smartphones erfasst wird (Daniëls et al., 2020; Maekawa et al., 2018; Schweitzer et al., 2017).

Studien zu langfristigen Veränderungen von kognitiven Funktionen und Blutdruck, konnten Zusammenhänge zwischen Hypertonie und Hypotonie und Aufmerksamkeit, Gedächtnis und Exekutivfunktionen aufzeigen (Novak & Hajjar, 2010; Power et al., 2013). Die Psychopathologie dazu ist aber noch nicht hinreichend geklärt. Es fehlt an Informationen zu Ursache-Wirkungszusammenhängen und den zeitlichen Prozessen, die zu diesen Zusammenhängen führen. Assoziationen auf momentaner Ebene zwischen Blutdruck und kognitiven Funktionen, wie z.B. Konzentrationsfähigkeit und Arbeitsgedächtniskapazität, wären denkbar und könnten Aufschluss über unmittelbare Wirkzusammenhänge geben.

4.5. Schlussfolgerungen und Perspektive

Die Ergebnisse der Analysen verdeutlichen die Notwendigkeit einer multimodalen Betrachtung der Stressentstehung und -verarbeitung und möglichen Konsequenzen im universitären Bereich. Ambulantes Assessment bietet die Möglichkeit Stressprozesse im universitären Alltag von Studierenden multimodal zu untersuchen. E-Diaries können Veränderungen im Alltag auf mehreren Analyseebenen erfassen und somit können Prozesse auf den unterschiedlichen Ebenen differenziert analysiert und bewertet werden. Hierbei sollte die Betrachtungsweise gemäß einer hierarchischen Struktur erfolgen, bei der die Einflussfaktoren und Auswirkungen nicht nur auf Personenebene (*trait*-Ebene), sondern auch auf Situationsebene (*state*-Ebene), aber auch auf Strukturebene (vorgegebene Organisation des Studiums) miteinbezogen werden. Das Verständnis des Zusammenspiels von stressreichen Ereignissen, Strukturebene, *state*- und *trait*-Faktoren und deren Folgen für die Person und die darauffolgenden Regenerationsprozesse kann eine gute Datenbasis für die effiziente Umsetzung von Interventionen zur Prävention von körperlichen und psychischen Erkrankungen liefern.

5. LITERATURVERZEICHNIS

Adolphs, R., Cahill, L., Schul, R., & Babinsky, R. (1997). Impaired declarative memory for emotional material following bilateral amygdala damage in humans. *Learning and Memory*, *4*(3), 291–300.

Alloway, T. P., & Copello, E. (2013). Working Memory: The what, the why, and the how. *The Australian Educational and Developmental Psychologist*, *30*(2), 105–118.

Almela, M., van der Meij, L., Hidalgo, V., Villada, C., & Salvador, A. (2012). The cortisol awakening response and memory performance in older men and women. *Psychoneuroendocrinology*, *37*(12), 1929–1940.

Baker, S. R. (2004). Intrinsic, extrinsic, and amotivational orientations: Their role in university adjustment, stress, well-being, and subsequent academic performance. *Current Psychology*, *23*(3), 189–202.

Barta, W. D., Tennen, H., & Litt, M. D. (2012). Measurement reactivity in diary research. In M. R. Mehl, & T. S. Conner (Hg.), *Handbook of Research Methods for Studying Daily Life* (pp. 108–123). The Guilfold Press.

Batson, C. D., Shaw, L. L. & Oleson, K. C. (1992). Differentiating affect, mood, and emotion: Toward functionally based conceptual distinctions. In *Review of personality and social psychology, No. 13. Emotion* (pp. 294–326). Sage Publications, Inc.

Beedie, C., Terry, P. & Lane, A. (2005). Distinctions between emotion and mood. *Cognition and Emotion, 19(6)*, 847–878.

Brose, A., Wichers, M., & Kuppens, P. (2017). Daily stressful experiences precede but do not succeed depressive symptoms: Results from a longitudinal experience sampling study. *Journal of Social and Clinical Psychology*, *36*(3), 196–220.

Burger, A. M., & Bless, H. (2016). Affect and the weight of idealistic versus pragmatic concerns in decision situations. *European Journal of Social Psychology*, *46*(3), 323–340.

Calabrese, E. J. (2008). Stress biology and hormesis: The Yerkes-Dodson law in psychology-a special case of the hormesis dose response. *Critical reviews in toxicology*, *38*(5), 453–462.

Carver, C. S., & Connor-Smith, J. (2010). Personality and coping. *Annual Review of Psychology*, *61*, 679–704.

Carver, C. S., Scheier, M. F., & Weintraub, J. K. (1989). Assessing coping strategies: A theoretically based approach. *Journal of personality and social psychology*, *56*(2), 267–283.

Cohen, L. H., Gunthert, K. C., Butler, A. C., O'Neill, S. C., & Tolpin, L. H. (2005). Daily affective reactivity as a prospective predictor of depressive symptoms. *Journal of Personality*, *73*(6).

Conen, D., & Bamberg, F. (2008). Noninvasive 24-h ambulatory blood pressure and cardiovascular disease: A systematic review and meta-analysis. *Journal of Hypertension*, *26*(7), 1290–1299.

Conner, T. S., & Reid, K. A. (2012). Effects of intensive mobile happiness reporting in daily life. *Social Psychological and Personality Science*, *3*(3), 315–323.

Curby, K. M., Johnson, K. J., & Tyson, A. (2012). Face to face with emotion: holistic face processing is modulated by emotional state. *Cognition and Emotion*, *26*(1), 93–102.

Curci, A., Lanciano, T., Soleti, E., & Rimé, B. (2013). Negative emotional experiences arouse rumination and affect working memory capacity. *Emotion (Washington, D.C.)*, *13*(5), 867–880.

Daniëls, N. E. M., Bartels, S. L., Verhagen, S. J. W., van Knippenberg, R. J. M., Vugt, M. E. de, & Delespaul, P. A. E. G. (2020). Digital assessment of working memory and processing speed in everyday life: Feasibility, validation, and lessons-learned. *Internet interventions*, *19*, 100300.

Davis, M. A. (2009). Understanding the relationship between mood and creativity: A meta-analysis. *Organizational Behavior and Human Decision Processes*, *108*(1), 25–38.

Deci, E. L., & Ryan, R. M. (1993). Die Selbstbestimmungstheorie der Motivation und ihre Bedeutung für die Pädagogik. *Zeitschrift für Pädagogik, 39(2)*, 223-238.

Duan, H., Yuan, Y., Zhang, L., Qin, S., Zhang, K., Buchanan, T. W., & Wu, J. (2013). Chronic stress exposure decreases the cortisol awakening response in healthy young men. *Stress*, *16*(6), 630–637.

Ekman, P., & Davidson, R. J. (1994). *The nature of emotion: Fundamental questions. Series in affective science.* Oxford University Press.

Ennis, G. E., Moffat, S. D., & Hertzog, C. (2016). The cortisol awakening response and cognition across the adult lifespan. *Brain and cognition*, *105,* 66–77.

Forgas, J. P. (2011). She just doesn't look like a philosopher…? Affective influences on the halo effect in impression formation. *European Journal of Social Psychology*, *41*(7), 812–817.

Fries, E., Dettenborn, L., & Kirschbaum, C. (2009). The cortisol awakening response (CAR): Facts and future directions. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, *72*(1), 67–73.

Gable, P., & Harmon-Jones, E. (2010). The motivational dimensional model of affect: implications for breadth of attention, memory, and cognitive categorization. *Cognition and Emotion*, *24*(2), 322–337.

Gartland, N., O'Connor, D. B., Lawton, R., & Ferguson, E. (2014). Investigating the effects of conscientiousness on daily stress, affect and physical symptom processes: A daily diary study. *British Journal of Health Psychology*, *19*(2), 311–328.

Gasper, K., & Spencer, L. A. (2018). Affective ingredients: recipes for understanding how affective states alter cognitive outcomes. In E. Diener, S. Oishi, & L. Tay (Hg.), *Handbook of Well-Being*. DEF Publishers.

Gasper, K., & Hackenbracht, J. (2015). Too busy to feel neutral: reducing cognitive resources attenuates neutral affective states. *Motivation and Emotion*, *39*(3), 458–466.

Gigerenzer, G. (2008). Why heuristics work. *Perspectives on Psychological Science: A Journal of the Association for Psychological Science*, *3*(1), 20–29.

Gramer, M. (2003). Cognitive appraisal, emotional and cardiovascular responses of high and low dominant subjects in active performance situations. *Personality and Individual Differences*, *34*(7), 1303–1318.

Greifeneder, R., & Bless, H. (2008). Depression and reliance on ease-of-retrieval experiences. *European Journal of Social Psychology*, *38*(2), 213–230.

Groß, L. (2010). Bachelor- und Masterstudiengänge – Eine (zeitliche) Belastungsprobe für Studierende und Lehrende? Ein Beitrag zur Berechnung von Lern- und Lehrleistung als ein Aspekt des Forschungsprojekts ZEITLast. In *Fokus Medienpädagogik. Aktuelle Forschungs- und Handlungsfelder.* (S. 389–394).

Gump, B. B. & Matthews, K. A. (1999). Do background stressors influence reactivity to and recovery from acute stressors? *Journal of Applied Social Psychology*, *29*(3), 469–494.

Harari, G. M., Gosling, S. D., Wang, R., Chen, F., Chen, Z., & Campbell, A. T. (2017). Patterns of behavior change in students over an academic term: a preliminary study of activity and sociability behaviors using smartphone sensing methods. *Computers in Human Behavior*, *67*, 129–138.

Hernando, A., Lazaro, J., Gil, E., Arza, A., Garzon, J. M., Lopez-Anton, R., La Camara, C. de, Laguna, P., Aguilo, J., & Bailon, R. (2016). Inclusion of respiratory frequency information in heart rate variability analysis for stress assessment. *IEEE Journal of Biomedical and Health Informatics*, *20*(4), 1016–1025.

Herrero, N., Gadea, M., Rodríguez-Alarcón, G., Espert, R., & Salvador, A. (2010). What happens when we get angry? Hormonal, cardiovascular and asymmetrical brain responses. *Hormones and behavior*, *57*(3), 276–283.

Het, S., Schoofs, D., Rohleder, N., & Wolf, O. T. (2012). Stress-induced cortisol level elevations are associated with reduced negative affect after stress: Indications for a mood-buffering cortisol effect. *Psychosomatic Medicine*, *74*(1), 23–32.

Het, S., & Wolf, O. T. (2007). Mood changes in response to psychosocial stress in healthy young women: Effects of pretreatment with cortisol. *Behavioral Neuroscience*, *121*(1), 11–20.

Hill, E. E., Zack, E., Battaglini, C., Viru, M., Viru, A., & Hackney, A. C. (2008). Exercise and circulating cortisol levels: The intensity threshold effect. *Journal of Endocrinological Investigation*, *31*(7), 587–591.

Hoyt, L. T., Zeiders, K. H., Ehrlich, K. B., & Adam, E. K. (2016). Positive upshots of cortisol in everyday life. *Emotion (Washington, D.C.)*, *16*(4), 431–435.

Johnson, K. J., Waugh, C. E., & Fredrickson, B. L. (2010). Smile to see the forest: Facially expressed positive emotions broaden cognition. *Cognition and Emotion*, *24*(2), 299–321.

Juth, V., Dickerson, S. S., Zoccola, P. M., & Lam, S. (2015). Understanding the utility of emotional approach coping: Evidence from a laboratory stressor and daily life. *Anxiety, Stress, and Coping*, *28*(1), 50-70.

Kalisch, R., Baker, D. G., Basten, U., Boks, M. P., Bonanno, G. A., Brummelman, E., Chmitorz, A., Fernàndez, G., Fiebach, C. J., Galatzer-Levy, I., Geuze, E., Groppa, S., Helmreich, I., Hendler, T., Hermans, E. J., Jovanovic, T., Kubiak, T., Lieb, K., Lutz, B., . . ., & Kleim, B.

(2017). The resilience framework as a strategy to combat stress-related disorders. *Nature Human Behaviour*, *1*(11), 784–790.

Kamarck, T. W., Janicki, D. L., Shiffman, S. S., Polk, D. E., Muldoon, M. F., Liebenauer, L. L., & Schwartz, J. E. (2002). Psychosocial demands and ambulatory blood pressure: A field assessment approach. *Physiology & Behavior, 77*(4), 699–704.

Karasek, R. A. (1979). Job demands, job decision latitude, and mental strain: Implications for job redesign. *Administrative Science Quarterly*, *24*(2), 285-308.

Kausar, R. (2010). Perceived stress, academic workload and use of coping strategies by university students. *Journal of Behavioural Sciences, 20,* 31-45.

Kazén, M., Kuenne, T., Frankenberg, H., & Quirin, M. (2012). Inverse relation between cortisol and anger and their relation to performance and explicit memory. *Biological Psychology*, *91*(1), 28–35.

Kember, D., NG, S., TSE, H., Wong, E. T. T., & Pomfret, M. (1996). An examination of the interrelationships between workload, study time, learning approaches and academic outcomes. *Studies in Higher Education*, *21*(3), 347–358.

Kloet, E. R. de, Oitzl, M. S., & Joëls, M. (1999). Stress and cognition: are corticosteroids good or bad guys? *Trends in Neurosciences*, *22*(10), 422–426.

Kramer, A. C., Neubauer, A. B., Stoffel, M., Voss, A., & Ditzen, B. (2019). Tomorrow's gonna suck: Today's stress anticipation predicts tomorrow's post-awakening cortisol increase. *Psychoneuroendocrinology*, *106*, 38–46.

Lacey, K., Zaharia, M.D., Griffiths, J., Ravindran, A.V., Merali, Z., & Anisman, H. (2000). A prospective study of neuroendocrine and immune alterations associated with the stress of an oral academic examination among graduate students. *Psychoneuroendocrinology*, *25*(4), 339–356.

Landrum, E. R., Turrisi, R., & Brandel, J. M. (2006). College students' time: course level, time of semester, and grade earned. *Psychological Reports*, *98*, 675–682.

Landsbergis, P. A., Dobson, M., Koutsouras, G., & Schnall, P. (2013). Job strain and ambulatory blood pressure: A meta-analysis and systematic review. *American Journal of Public Health*, *103*(3), e61-71.

Law, R., Hucklebridge, F., Thorn, L., Evans, P., & Clow, A. (2013). State variation in the cortisol awakening response. *Stress (Amsterdam, Netherlands)*, *16*(5), 483–492.

Lazarus, R. S. (1993). From psychological stress to the emotions: A history of changing outlooks. *Annual Reviews of Psychology*, *44*, 1–21.

Lazarus, R.S., & Folkman, S. (1984). *Stress, appraisal, and coping*. Springer.

Lin, C. H. (2009). Exploring facets of a social network to explicate the status of social support and its effects on stress. *Social Behavior and Personality: An International Journal*, *37*(5), 701–710.

Lyubormirsky, S., Tucker, K. L., Caldwell, N. D., & Berg, K. (1999). Why ruminators are poor problem solvers: Clues from the phenomenology of dysphoric rumination. *Journal of Personality and Social Psychology*, *77*(5), 1041–1060.

Maekawa, T., Anderson, S. J., Brecht, M. de, & Yamagishi, N. (2018). The effect of mood state on visual search times for detecting a target in noise: An application of smartphone technology. *PloS One*, *13*(4), e0195865.

Matheson, K., & Anisman, H. (2009). Anger and shame elicited by discrimination: Moderating role of coping on action endorsements and salivary cortisol. *European Journal of Social Psychology*, *39*(2), 163–185.

McEwen, B. S. (1998). Stress, adaptation, and disease. Allostasis and allostatic load. *Annals of the New York Academy of Sciences*, *840*, 33–44.

Middeke, M. (2005). Die U-förmige Beziehung zwischen nächtlichem Blutdruck und Organschäden [U-shaped relationship between nocturnal blood pressure and organ impairment]. *Deutsche medizinische Wochenschrift (1946)*, *130*(46), 2640–2642.

Miller, G. E., Chen, E., & Zhou, E. S. (2007). If it goes up, must it come down? Chronic stress and the hypothalamic-pituitary-adrenocortical axis in humans. *Psychological Bulletin*, *133*(1), 25–45.

Moons, W. G., Eisenberger, N. I., & Taylor, S. E. (2010). Anger and fear responses to stress have different biological profiles. *Brain, Behavior, and Immunity*, *24*(2), 215–219.

Multrus, F., Bargel, T., & Ramm, M. (2008). *Studiensituation und studentische Orientierungen.* 10. Studierendensurvey an Universitäten und Fachhochschulen. Langfassung. Bundesministerium für Bildung und Forschung.

Myin-Germeys, I., Peeters, F., Havermans, R., Nicolson, N. A., Vries, M. W., Delespaul, P. A., & van Os, J. (2003). Emotional reactivity to daily life stress in psychosis and affective disorder: An experience sampling study. *Acta Psychiatrica Scandinavica*, *107*(2), 124–131.

Novak, V., & Hajjar, I. (2010). The relationship between blood pressure and cognitive function. *Nature Reviews. Cardiology*, *7*(12), 686–698.

O'Brien, E., Asmar, R., Beilin, L., Imai, Y., Mallion, J. M., Mancia, G., Mengden, T., Myers, M., Padfield, P., Palatini, P., Parati, G., Pickering, T., Redon, J., Staessen, J., Stergiou, G., & Verdecchia, P. (2003). European Society of Hypertension recommendations for conventional, ambulatory and home blood pressure measurement. *Journal of Hypertension*, *21*(5), 821–848.

O'Connor, D. B., Walker, S., Hendrickx, H., Talbot, D., & Schaefer, A. (2013). Stress-related thinking predicts the cortisol awakening response and somatic symptoms in healthy adults. *Psychoneuroendocrinology*, *38*(3), 438–446.

O'Hara, R. E., Armeli, S., Boynton, M. H., & Tennen, H. (2014). Emotional stress-reactivity and positive affect among college students: The role of depression history. *Emotion (Washington, D.C.)*, *14*(1), 193–202.

Pan, Y., & Gauvain, M. (2012). The continuity of college students' autonomous learning motivation and its predictors: A three-year longitudinal study. *Learning and Individual Differences*, *22*(1), 92–99.

Papousek, I., Nauschnegg, K., Paechter, M., Lackner, H. K., Goswami, N., & Schulter, G. (2010). Trait and state positive affect and cardiovascular recovery from experimental academic stress. *Biological Psychology*, *83*(2), 108–115.

Parrish, B. P., Cohen, L. H., & Laurenceau, J. P. (2011). Prospective relationship between negative affective reactivity to daily stress and depressive symptoms. *Journal of Social and Clinical Psychology*, *30*(3), 270–296.

Pascoe, M. C., Hetrick, S. E., & Parker, A. G. (2020). The impact of stress on students in secondary school and higher education. *International Journal of Adolescence and Youth*, *25*(1), 104–112.

Pickering, T. G., Davidson, K., Gerin, W., & Schwartz, J. E. (2002). Masked hypertension. *Hypertension (Dallas, Tex: 1979)*, *40*(6), 795–796.

Powell, D. J., & Schlotz, W. (2012). Daily life stress and the cortisol awakening response: Testing the anticipation hypothesis. *PloS One*, *7*(12), e52067.

Power, M. C., Tchetgen, E. J. T., Sparrow, D., Schwartz, J., & Weisskopf, M. G. (2013). Blood pressure and cognition: Factors that may account for their inconsistent association. *Epidemiology*, *24*(6), 886–893.

Pruessner, J. C., Wolf, O. T., Hellhammer, D. H., Buske-Kirschbaum, A., Auer, K., Jobst, S., Kaspers, F., & Kirschbaum, C. (1997). Free cortisol levels after awakening: A reliable biological marker for the assessment of adrenocortical activity. *Life Sciences*, *61*(26), 2539–2549.

Puterman, E., O'Donovan, A., Adler, N. E., Tomiyama, A. J., Kemeny, M., Wolkowitz, O. M., & Epel, E. (2011). Physical activity moderates effects of stressor-induced rumination on cortisol reactivity. *Psychosomatic Medicine*, *73*(7), 604–611.

Ram, N., & Gerstorf, D. (2009). Time-structured and net intraindividual variability: Tools for examining the development of dynamic characteristics and processes. *Psychology and Aging*, *24*(4), 778–791.

Rau, R. (2001). *Arbeit - Erholung - Gesundheit: Ein Beitrag zur Occupational Health Psychology*. Habilitationsschrift.

Rau, R. (2004). Job strain or healthy work: a question of task design. *Journal of Occupational Health Psychology*, *9*(4), 322–338.

Rau, R., Georgiades, A., Fredrikson, M., Lemne, C., & Faire, U. de (2001). Psychosocial work characteristics and perceived control in relation to cardiovascular rewind at night. *Journal of Occupational Health Psychology*, *6*(3), 171–181.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2. Aufl.). *Advanced quantitative techniques in the social sciences: Bd. 1*. SAGE Publications.

Robotham, D. (2008). Stress among higher education students: Towards a research agenda. *Higher Education*, *56*(6), 735–746.

Rodriguez, C. J., Burg, M. M., Meng, J., Pickering, T. G., Jin, Z., Sacco, R. L., Boden-Albala, B., Homma, S., & Di Tullio, M. R. (2008). Effect of social support on nocturnal blood pressure dipping. *Psychosomatic Medicine*, *70*(1), 7–12.

Ruiz-Gallardo, J.-R., Castaño, S., Gómez-Alday, J. J., & Valdés, A. (2011). Assessing student workload in problem-based learning: Relationships among teaching method, student workload and achievement. A case study in natural sciences. *Teaching and Teacher Education*, *27*(3), 619–627.

Runyan, J. D., Steenbergh, T. A., Bainbridge, C., Daugherty, D. A., Oke, L., & Fry, B. N. (2013). A smartphone ecological momentary assessment/intervention "app" for collecting real-time data and promoting self-awareness. *PloS one*, *8*(8), e71325.

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review, 110(1)*, 145–172.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78.

Schilling, T. M., Kölsch, M., Larra, M. F., Zech, C. M., Blumenthal, T. D., Frings, C., & Schächinger, H. (2013). For whom the bell (curve) tolls: Cortisol rapidly affects memory retrieval by an inverted U-shaped dose-response relationship. *Psychoneuroendocrinology*, *38*(9), 1565–1572.

Schlotz, W. (2019). Investigating associations between momentary stress and cortisol in daily life: What have we learned so far? *Psychoneuroendocrinology*, *105*, 105–116.

Schlotz, W., Kumsta, R., Layes, I., Entringer, S., Jones, A., & Wüst, S. (2008). Covariance between psychological and endocrine responses to pharmacological challenge and psychosocial stress: A question of timing. *Psychosomatic medicine*, *70*(7), 787–796.

Schmidt, L. I., Sieverding, M., Scheiter, F., & Obergfell, J. (2015). Predicting and explaining students' stress with the Demand–Control Model: Does neuroticism also matter? *Educational Psychology*, *35*(4), 449–465.

Schulmeister, R., & Metzger, C. (Hg.). (2011). *Die Workload im Bachelor: Zeitbudget und Studierverhalten: Eine empirische Studie*. Waxmann.

Schweitzer, P., Husky, M., Allard, M., Amieva, H., Pérès, K., Foubert-Samier, A., Dartigues, J.-F., & Swendsen, J. (2017). Feasibility and validity of mobile cognitive testing in the investigation of age-related cognitive decline. *International Journal of Methods in Psychiatric Research*, *26*(3).

Senécal, C., Koestner, R., & Vallerand, R. J. (1995). Self-regulation and academic procrastination. *The Journal of Social Psychology*, *135*(5), 607–619.

Shrout, P. E., Stadler, G., Lane, S. P., McClure, M. J., Jackson, G. L., Clavél, F. D., Iida, M., Gleason, M. E. J., Xu, J. H., & Bolger, N. (2018). Initial elevation bias in subjective reports. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(1), E15-E23.

Smith, C., Galland, B., Taylor, R., & Meredith-Jones, K. (2020). ActiGraph GT3X+ and actical wrist and hip worn accelerometers for sleep and wake indices in young children using an automated algorithm: Validation with polysomnography. *Frontiers in Psychiatry*, *10*: 958.

Southwick, S. M., & Charney, D. S. (2012). The science of resilience: Implications for the prevention and treatment of depression. *Science (New York, N.Y.)*, *338*(6103), 79–82.

Spangler, G., Pekrun, R., Kramer, K., & Hofman, H. (2002). Students' emotions, physiological reactions, and coping in academic exams. *Anxiety, Stress & Coping*, *15*(4), 413–432.

Stalder, T., Kirschbaum, C., Kudielka, B. M., Adam, E. K., Pruessner, J. C., Wüst, S., Dockray, S., Smyth, N., Evans, P., Hellhammer, D. H., Miller, R., Wetherell, M. A., Lupien, S. J., & Clow, A. (2016). Assessment of the cortisol awakening response: expert consensus guidelines. *Psychoneuroendocrinology*, *63*, 414–432.

Stallman, H. M. (2010). Psychological distress in university students: A comparison with general population data. *Australian Psychologist*, *45*(4), 249–257.

Stallman, H. M., & Hurst, C. P. (2016). The university stress scale: Measuring domains and extent of stress in university students. *Australian Psychologist*, *51*(2), 128–134.

Steptoe, A., Leigh, G. E., Hamer, M., & Wardle, J. (2007). Neuroendocrine and cardiovascular correlates of positive affect measured by ecological momentary assessment and by questionnaire. *Psychoneuroendocrinology*, *32*(1), 56–64.

Steptoe, A. (2000). Stress, social support and cardiovascular activity over the working day. *International Journal of Psychophysiology*, *37*(3), 299–308.

Steptoe, A., & Wardle, J. (2005). Positive affect and biological function in everyday life. *Neurobiology of aging*, *26 Suppl 1*, 108–112.

Stinebrickner, R., & Stinebrickner, T. R. (2004). Time-use and college outcomes. *Journal of Econometrics*, *121*(1-2), 243–269.

Stone, A. A., Broderick, J. E., Schwartz, J. E., Shiffman, S., Litcher-Kelly, L., & Calvanese, P. (2003). Intensive momentary reporting of pain with an electronic diary: Reactivity, compliance, and patient satisfaction. *Pain*, *104*(1), 343–351.

Stone, A. A., Shiffman, S. S., Schwartz, J. E., Broderick, J. E., & Hufford, M. R. (2002). Patient non-compliance with paper diaries. *British Medical Journal*, *324*(7347), 1193–1194.

Tanner, J. R., Stewart, G., Maples, G. M., & Totaro, M. W. (2008). How business students spend their time—do they really know? *Research in Higher Education Journal*, Available at: http://www.aabri.com/manuscripts/09152.pdf (accessed January 2019).

Trull, T. J., & Ebner-Priemer, U. (2013). Ambulatory assessment. *Annual Review of Clinical Psychology*, *9*, 151–176.

Vallerand, R. J., & Bisonnette (1992). Intrinsic, extrinsic, and amotivational styles as predictors of behavior: A prospective study. *Journal of Personality*, *60*(3), 600–618.

van Winkel, M., Nicolson, N. A., Wichers, M., Viechtbauer, W., Myin-Germeys, I., & Peeters, F. (2015). Daily life stress reactivity in remitted versus non-remitted depressed individuals. *European Psychiatry: The Journal of the Association of European Psychiatrists*, *30*(4), 441–447.

Vedhara, K., Hyde, J., Gilchrist, I.D., Tytherleigh, M., & Plummer, S. (2000). Acute stress, memory, attention and cortisol. *Psychoneuroendocrinology*, *25*(6), 535–549.

Weidner, G., Kohlmann, C.-W., Dotzauer, E., & Burns, L. R. (1996). The effects of academic stress on health behaviors in young adults. *Anxiety, Stress, and Coping*, *9*(2), 123–133.

Weik, U., & Deinzer, R. (2010). Alterations of postawakening cortisol parameters during a prolonged stress period: Results of a prospective controlled study. *Hormones and Behavior*, *58*(3), 405–409.

Weinstein, C. E., Acee, T. W., & Jung, J. (2011). Self-regulation and learning strategies. *New Directions for Teaching and Learning*, *2011*(126), 45–53.

Wilhelm, P. & Perrez, M. (2013). *A history of research conducted in daily life (Scientific Report Nr. 170)*. Department of Psychology, University of Fribourg, Switzerland. Retrieved from: http://www.unifr.ch/psycho/site/assets/files/klinisch/Wilhelm%20&%20Perrez%20(2013).%20A%20history%20of%20research%20coducted%20in%20daily%20life.pdf

Wilhelm, P., & Schoebi, D. (2007). Assessing mood in daily life: Structural validity, sensitivity to change, and reliability of a short-scale to measure three basic dimensions of mood. *European Journal of Psychological Assessment*, *23*(4), 258–267.

Wilks, S. E. (2008). Resilience amid academic stress: The moderating impact of social support among social work students. *Advances in Social Work*, *9*(2), 106–125.

Xiang, Z., Tan, S., Kang, Q., Zhang, B., & Zhu, L. (2019). Longitudinal effects of examination stress on psychological well-being and a possible mediating role of self-esteem in chinese high school students. *Journal of Happiness Studies*, *20*(1), 283–305.

Yang, H., Yang, S., & Isen, A. M. (2013). Positive affect improves working memory: Implications for controlled cognitive processing. *Cognition and Emotion*, *27*(3), 474–482.

Yano, Y., & Kario, K. (2012). Nocturnal blood pressure and cardiovascular disease: A review of recent advances. *Hypertension Research*, *35*(7), 695–701.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, *18*, 459–482.

Zawadzki, M. J., Mendiola, J., Walle, E. A., & Gerin, W. (2016). Between-person and within-person approaches to the prediction of ambulatory blood pressure: The role of affective valence and intensity. *Journal of Behavioral Medicine,* 39*(5),* 757–766.

6. PUBLIKATIONEN (PEER-REVIEWED)

(1) **Koudela-Hamila, S.**, Santangelo, P., Ebner-Priemer, U. W., & Schlotz, W. (submitted). Under which circumstances does academic workload lead to stress? Explaining intraindividual differences by using the cortisol-awakening response as a moderator. *Journal of Psychophysiology*.

(2) **Koudela-Hamila, S.**, Smyth J., Santangelo, P., & Ebner-Priemer, U. W. (2020). Examination stress in academic students: A multimodal, real-time, real-life investigation of reported stress, social contact, blood pressure, and cortisol. *Journal of American College Health.* Online ahead of print.

(3) Santangelo, P. S., Holtmann, J., Hosoya, G., Bohus, M., Kockler, T. D., **Koudela-Hamila, S.**, Eid, M., & Ebner-Priemer, U. W. (2020). Within- and between-person effects of self-esteem and affective state as antecedents and consequences of dysfunctional behaviors in the everyday lives of patients with borderline personality disorder. *Clinical Psychological Science, 8* (3), 428-449.

(4) **Koudela-Hamila, S.**, Grund, A., Santangelo, P., & Ebner-Priemer, U. W. (2019). Valence and motivation as predictors of student time use in everyday life: An experience sampling study. *Frontiers in Psychology, 10*: 1430.

(5) Santangelo, P., Koenig, J., Kockler, T. D., Eid, M., Holtmann, J., **Koudela-Hamila, S.**, Parzer, P., Resch, F., Bohus, M., Kaess, M., & Ebner-Priemer, U. W. (2018). Affective instability across the life span in Borderline Personality Disorder – A cross-sectional e-diary study. *Acta Psychiatrica Scandinavica, 138,* 409-419.

(6) Santangelo, P. S., Reinhard, I., **Koudela-Hamila, S.**, Bohus, M., Holtmann, J., Eid, M., & Ebner-Priemer, U. W. (2017). The temporal interplay of self-esteem instability and affective instability in Borderline Personality Disorder patients' everyday life. *Journal of Abnormal Psychology, 126,* 1057-1065.

(7) Priebe, K., Kleindienst, N., Zimmer, J., **Koudela, S.**, Ebner-Priemer, U. W., & Bohus, M. (2013). Frequency of intrusions and flashbacks in patients with posttraumatic stress disorder related to childhood sexual abuse: An electronic diary study. *Psychological Assessment, 25*, 1370-1376.

(8) Bossmann, T., Kanning, M., **Koudela, S.**, Hey, S., & Ebner-Priemer, U. W. (2013). The association between short periods of everyday life activities and affective states: A replication study using ambulatory assessment. *Frontiers in Movement Science and Sport Psychology, 4:* 102.

(9) Huffziger, S., Ebner-Priemer, U. W., Eisenbach, C., **Koudela, S.**, Reinhard, I., Zamoscik, V., Kirsch, P., & Kuehner, C. (2013). Induced ruminative and mindful attention in everyday life: An experimental ambulatory assessment study. *Journal of Behavior Therapy and Experimental Psychiatry*, *44*, 322-328.

(10) Ebner-Priemer, U. W., **Koudela, S.**, Mutz, G., & Kanning, M. (2013). Interactive multimodal ambulatory monitoring to investigate the association between physical activity and mood. *Frontiers in Movement Science and Sport Psychology*, *3*: 596.

(11) Huffziger, S., Ebner-Priemer, U. W., **Koudela, S.**, Reinhard, I., & Kuehner, C. (2012). Induced rumination in everyday life: Advancing research approaches to study rumination. *Personality and Individual Differences*, *53,* 790–795.

(12) Santangelo, P., **Koudela, S.,** & Ebner-Priemer, U. W. (2012). What does psychology and psychiatry need from Mobile Systems – an end-user perspective. *Mobile Systems for Computational Social Science ACM Digital Library, 1-4*.