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ORIGINAL ARTICLE

I could do it now, but I'd rather (forget to) do it later: examining links between procrastination and prospective memory failures

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Abstract
Prospective memory (PM) represents the ability to remember to perform planned actions after a certain delay. As previous studies suggest that even brief task-delays can negatively affect PM performance, the current study set out to examine whether procrastination (intentionally delaying task execution despite possible negative consequences) may represent a factor contributing to PM failures. Specifically, we assessed procrastination (via a standardized questionnaire as well as an objective behavioral measure) and PM failures (via a naturalistic PM task) in 92 young adults. Results show that participants' self-reports as well as their actual procrastination behavior predicted the number of PM failures, corroborating the impact of procrastination on PM. Subsequent cluster analyses suggest three distinct procrastination profiles (non-procrastinators, conscious procrastinators and unconscious procrastinators), providing new conceptual insights into different mechanisms of how procrastinating may lead to forgetting to perform planned tasks.

Introduction

Most individuals reading this paper will already have experienced the following situation: after a busy day at work, we look at our mobile phone and suddenly feel bad, as we realize that we (again) forgot to reply to a friend's text message. Such incidents are associated to prospective memory (PM), our ability to remember to perform a planned action (i.e. replying to a friend) at a particular moment in the future (i.e. during lunch break; Einstein & McDaniel, 1990; Kvavilashvili & Ellis, 1996). PM abilities allow us to remember to attend a meeting at a specific time, to call a family member on their birthday, to take our medication before breakfast, or to turn off the stove after preparing a meal. PM, therefore, plays a crucial role in everyday functioning across multiple domains, such as academic achievement, professional success, social relations, quality of life, functional independence and personal safety (e.g., Bedard, Verma, Collins, Song, & Paquet, 2016; Chen, Lian, Yang, Liu, & Meng, 2017; Hering, Kliegel, Rendell, Craik, & Rose, 2018; Raskin & Sohlberg, 1996; Schmitter-Edgecombe, Woo, & Greeley, 2009; Woods et al., 2015; Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012; Zeintl, Kliegel, Rast, & Zimprich, 2006).

Although intact PM functioning is essential to manage our daily lives, PM failures unfortunately are frequent: studies show that PM failures represent 50–80% of everyday memory failures (Crovitz & Daniel, 1984; Haas, Zuber, Kliegel, & Ballhausen, 2020; Terry, 1988). Consequently, for the last 3 decades, one of the main goals in PM research has been to uncover the factors contributing to intact PM and those leading to PM failures (for a recent review, see Zuber & Kliegel, in press). So far, the literature has explored multiple domains, which can be separated into two groups: (1) factors that are inherent to the PM task (such as task setting, task difficulty, task importance or PM cue features; e.g., Hering, Phillips, & Kliegel, 2014; Mahy, Moses, & Kliegel, 2014; McDaniel & Einstein, 2000; Rendell & Thomson, 1999), and (2) factors that are related to the person that is

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performing the PM task (such as the person's age, cognitive resources, motivation or their stress-level; e.g., Aberle, Rendell, Rose, McDaniel, & Kliegel, 2010; Ballhausen, Hering, Rendell, & Kliegel, 2019a; Ballhausen, Kliegel, & Rimmele, 2019b; Henry, MacLeod, Phillips, & Crawford, 2004; Piefke & Glienke, 2017; Zuber, Kliegel, & Ihle, 2016).

Previous work in both research lines has considerably advanced our understanding of the predictors of PM performance. However, there is at least one person-related factor that has so far been largely neglected, although it is also linked to performing planned actions and thus might also relate to PM: procrastination. Procrastination can be defined as voluntarily delaying an intended course of actions, although one expects to be worse off due to the delay (Ferrari, 2001; Steel, Brothen, & Wambach, 2001). Despite its negative consequences, procrastination represents a widely spread phenomenon. One out of five adults indicate frequent problems with procrastination (Harriott & Ferrari, 1996), whereas that quota is even higher (approximately at 50%) in student populations (Steel, 2007). Considering how frequently procrastination occurs and how important intact PM is for one's everyday functioning, it seems crucial to know whether procrastination can lead to PM failures. But why might procrastination form a new factor contributing to PM failures? So far, the PM literature has largely worked under the implicit assumption that once an intention is consciously retrieved at the appropriate moment (i.e. remembering that one still has to answer a friend's message), it is immediately executed (Brandimonte, Einstein, & McDaniel, 1996; Kliegel, McDaniel, & Einstein, 2008; McDaniel & Einstein, 2007). A rare exception to this constitutes research on so-called 'delayed-execute' tasks, for which participants are asked to delay executing the retrieved intention by a short time (e.g., Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; Kelly, Hertzog, Hayes, & Smith, 2013; Kliegel & Jäger, 2006; McDaniel, Einstein, Stout, & Morgan, 2003; Schaper & Grundgeiger, 2018). This additional delay typically has a negative impact on PM performance, meaning that more PM failures occur when execution is delayed. However, delayed-execute tasks represent a very particular laboratory situation, first because participants are explicitly instructed to delay task execution (i.e. the delay becomes part of the task paradigm), and second because the delay typically designates a relatively brief period (i.e. seconds to minutes). In addition, even those paradigms did not consider the possibility that an individual may consciously *decide* to further delay executing an intention after having retrieved it (i.e. decide to postpone). Coming back to the initial example, throughout the day, one may spontaneously remember a particular prospective task (e.g., 'I still have to reply to my friend's message'), but instead of performing the task at that very moment, one would plan to do so later—which may often result in forgetting and not performing the prospective task after all. Following up on this hypothesis, the present study set out to explore a potential link between PM and intentional postponement (i.e. procrastination).

Although largely unexplored so far, the literature provides multiple arguments for a potential link between the two domains. First, procrastination and PM are both related to performing planned activities and accomplishing one's goals (e.g., Gustavson & Miyake, 2017; Scullin & McDaniel, 2010). Second, both have been associated to similar cognitive strategies and interventions: for example, the usage of implementation intentions (=linking a goal intention to a time and location of execution; Gollwitzer, 1999) has been suggested to reduce procrastination (Owens, Bowman, & Dill, 2008) but also to improve PM performance (Burkard et al., 2014; McFarland & Glisky, 2011; Zimmermann & Meier, 2010). Third, certain authors point toward an association between performing planned actions (PM) and one's tendency to postpone tasks (procrastination). For example, looking at the behavioral profile of frequent procrastinators, Svartdal, Granmo, and Færevaag (2018) suggest that "when an action possibility is available for intended behavior, procrastinators tend to delay behavior onset, both in actual behavior and in onset preferences, often instigating chains of events with negative consequences." (p. 1). Similarly, Kroese and de Ridder (2016) state that individuals might fail to enact planned intentions (e.g., taking a doctor's appointment, going to the gym), because they actively postpone such actions, which can negatively impact their long-term health.

Although these points speak in favor of a link between procrastination and PM, so far only one study has examined their potential association. Specifically, Altgassen, Scheres, and Edel (2019) recently demonstrated a strong link between the two domains ($r = -0.57$), with lower PM performance being associated to higher levels of procrastination self-ratings. Although this supported for the first time that the two domains are related, it is important to note that the authors focused on individuals with ADHD, who typically show deficits on cognitive processes related to both domains (such as time management, planning, and goal management). Thus, it has yet to be addressed whether these findings also apply to more general, non-clinical populations. Furthermore, if a similar link persisted in a non-clinical population, it would be important to better understand how the two constructs specifically relate to each other and which exact mechanisms underlie their relationship.

Thus, to uncover whether there are different mechanisms of how procrastination can lead to PM failures, we further aimed to assess procrastination using different types of measures, namely subjective self-reports and objective behavioral measures. Previous research has predominantly assessed procrastination via subjective, self-reported questionnaires such as the Pure Procrastination Scale (PPS; Steel,

2010). The PPS represents a particularly useful tool, as it addresses two distinct dimensions of procrastination (see Rebetez, Rochat, Gay, & Van der Linden, 2014; Zuber et al., 2020). The first, 'voluntary delay', englobes how often individuals actively decide to put off specific tasks and whether they typically have a preference for doing things later rather than earlier, even if this may have negative consequences. As the PM literature suggests that further delaying the execution of PM tasks has a negative impact on PM performance, it seems plausible that higher levels of voluntary delay would increase PM failures. The second dimension of the PPS, 'observed delay' (also labeled 'lateness' or 'timeliness', see Svartdal & Steel, 2017), describes more passive self-observations related to frequently running out of time or of generally being bad at meeting deadlines. This dimension, therefore, relates more strongly to time perception and time management, which both have also been shown to play a crucial role when performing PM tasks (Mioni & Stablum, 2014). Consequently, it further seems plausible that higher levels of observed delay could also lead to PM failures. By assessing two dimensions of procrastination, the PPS may provide first insights into differential mechanisms of how procrastination can lead to PM failures.

However, it seems important to underline that these subjective measures are prone to potential biases often observed in self-reports, such as over- or under-estimation due to participants' subjective perception or their self-esteem (e.g., Krause & Freund, 2014; Rotenstein, Davis, & Tatum, 2009). Thus, we additionally set out to assess procrastination with an objective measure that evaluates participants' actual behavior, by administering a real-life procrastination task (i.e. asking participants to accomplish a specific task before a certain deadline, see Zuber et al., 2020). Including an objective measure on one hand will allow investigating whether actual procrastination behavior can predict PM failures. On the other hand, in combination with self-reports, this will also allow to examine whether there are discrepancies between subjective and objective evaluations of procrastination, and whether this may affect participants' PM performance. Taken together, if procrastination proved to be an additional factoring contributing to PM failures, this could give novel insights into how PM failures may occur in everyday life and how they could be reduced.

Method

Participants

Ninety-three psychology students of the University of Geneva participated in the current study in exchange for course credits of a mandatory course in the second-year Bachelor's program. All participants that were included in subsequent analyses still required course credits. One participants did not complete all outcome measures and was thus excluded from subsequent analyses. The final sample consisted of 92 participants ($M = 22.74$, SD = 3.87; age range = 19–38 years; 12 men). All participants either spoke French as first language or had a proficient level of fluency. The study was approved by the ethics committee of the University of Geneva. All participants gave informed consent prior to taking part in the study.

Materials

Self-reported procrastination: pure procrastination scale (PPS)

The French version of the Pure Procrastination Scale (PPS; Rebetez et al., 2014) was conducted to assess self-reported procrastination. This scale consists of 11 statements, for which participants have to indicate on a 5-point Likert scale how accurately these statement describe them or their habits (1 = "very seldom or not true for me"; 5 = "very often true for me"). The PPS assesses two dimensions of procrastination: "voluntary delay" and "observed delay". While voluntary delay describes putting off actions or decisions actively (e.g., "I delay making decision until it's too late"), observed delay means to do so unintentionally or in a passive way (e.g. "I don't get things done in time"). To calculate each participant's level of self-reported voluntary delay (items 1–3, 5–8) and observed delay (items 9–11),[1] the Bartlett's factor score approach was applied (Bartlett, 1937; also see DiStefano, Zhu, & Mîndrilă, 2009). Bartlett's factor score approach calculates a standardized factor score for each participant, where the group mean is = 0.00 and where positive scores indicate that the participant scored above average on the respective factor.

Behavioral procrastination task

To assess behavioral procrastination in a naturalistic situation, participants were asked to perform a specific task before a particular deadline. In detail, participants were instructed at the end of the final laboratory session that they had to scan and return a signed study participation sheet via email before a specific date (i.e. one week prior to the course exam) to validate the course credits (see paragraph "Procedure" for further information). To avoid that participants

[1] An exploratory factor analysis on the PPS self-reports revealed that item 4 did not distinguish between the two dimensions of procrastination (high factor loadings on voluntary (=0.44) and observed delay (=0.49); for details, see Zuber et al. (2020). Consequently, item 4 was removed from subsequent analyses.

would have to perform the task too swiftly (i.e. to avoid an increased feeling of urgency) and to allow for enough time for various task-related behaviors (i.e. enough time to plan performing the task, but also to potentially procrastinate), this date was set so that all participants had at least three weeks to perform the task (for a different study setting a deadline of three weeks, see McCrea, Liberman, Trope, & Sherman, 2008). Due to the participants being tested on different days, the total amount of days each participant had before the deadline could vary between 21 and 39 days. The outcome measure was the number of days that elapsed before handing in the attendance sheet.

Prospective memory task

To assess PM in a naturalistic situation, we administered a modified "send-back" task, which has been used repeatedly to evaluate prospective abilities in everyday life (e.g., Aberle & Kliegel, 2010; Schnitzspahn, Ihle, Henry, Rendell, & Kliegel, 2011). In detail, participants had to remember to send pre-defined words via text messages to the experimenter at specific target-times (e.g., Tuesday at 10:35 send the word "cake"). At the beginning of the experiment, participants received a learning sheet, which depicted a table consisting of three columns and seven rows. For each row, the first column contained a half-day time-slot for a total of seven slots, one in the morning and one in the afternoon over 4 days, starting in the afternoon of the initial laboratory session (e.g., "Monday afternoon", "Tuesday morning", "Tuesday afternoon", etc.). The second column was empty and for each row participants had to define and write down a specific target-time on which they wanted to perform the PM task. They were instructed that they could choose any time they wanted except for full- and half-hours (meaning that they could for example choose the target-time 10:35, but neither 10:00 nor 10:30) and that each target-time could only be chosen once. After verifying that participants had defined different times for every half-day, the experimenter highlighted that for each row the third column contained a target-word (e.g., "cake") which had to be memorized in association with the target-time of that row. After doing this for all seven rows each row would correspond to the following pattern: time-slot | target-time | target-word (e.g., "Tuesday morning | 10:35 | cake"). Next, participants were instructed that for each of the rows they would have to send a text message containing the target-word at the target-time throughout the next four and a half days. For example, on Tuesday morning, at 10:35, they would have to send the word "cake" via text message. After verifying that participants had understood these instructions, they had 5 min to memorize the seven time-word pairs. Finally, they left the laboratory and the PM task started (meaning that they had to send the first text message containing the first target-word at the first target-time that was specified in the table). Messages received 6 min before or after the defined target-times were classified as correct PM answers (for similar approaches, see Cauvin, Moulin, Souchay, Schnitzspahn, & Kliegel, 2019; Schnitzspahn et al., 2011). The outcome measure was the total number of PM *failures* (i.e. *not* sending a message at corresponding target-time) divided by seven.

Table 1 Means, standard deviations, and range of behavioral procrastination and prospective memory performance

	M	SD	Range
Behavioral procrastination	15.17	10.83	0–41
Prospective memory failures	.35	.37	0–1

Behavioral procrastination = number of days for which the task was postponed; Prospective memory failures = ratio of non-performed prospective tasks (inversed accuracy score)

Procedure

The study consisted of four parts, a laboratory session, a home phase, a follow-up session and the target period for executing the behavioral procrastination task. All participants started the study with the laboratory session, during which they first gave informed consent, provided sociodemographic information and completed the PPS. Participants then received the instructions of the PM task, defined their PM target-times to send the text messages, and encoded the time-word pairs. This laboratory session lasted approximately 30 min. The home phase started in the afternoon after the laboratory session and lasted for 4 days, over which participants had to perform the PM task at the pre-defined target-times. After this period, participants came back to the laboratory for the follow-up session, during which they filled out different questionnaires (e.g., control questions about the PM task). The follow-up session again lasted approximately 30 min. Finally, they received a signed sheet, which confirmed their participation, and they were instructed that they had to send a scan of the sheet before the end of the semester via email to validate their course credits (i.e. the behavioral procrastination task).

Results

Table 1 depicts means, standard deviations, and range of participants' behavioral procrastination scores as well as of their PM failures (note that due to factor scoring, mean and standard deviation of both self-reported factors were $M = 0$ and $SD = 1$).

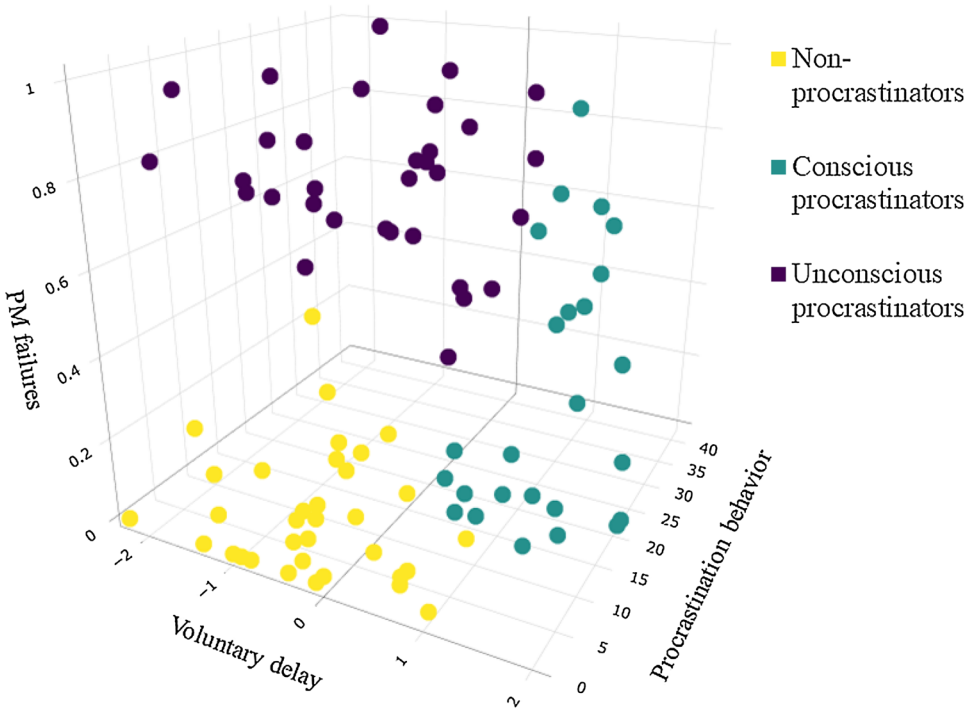

Fig. 1 3D scatterplot of cluster analysis. Voluntary delay = standardized scores of self-reported voluntary delay assessed via the Pure Procrastination Scale; positive scores represent scores above group-mean. Procrastination behavior = number of days for which task was postponed. PM failures = ratio of non-performed prospective tasks [inversed accuracy score, ranging from 0 to 1, with 0 representing no PM failure (i.e. perfect performance)]. A fully rotatable, 3D version can be accessed at https://rpubs.com/saschazuber/threeD_cluster_analysis (ad-blocker must be de-activated for rpubs.com)

Procrastination as predictor of PM failures

We performed a multiple linear regression to examine whether self-reported and/or behavioral procrastination predict participants' PM failures. Using a multiple linear regression model (instead of performing separate regressions for each predictor) has the advantage that it controls for co-variance between different predictors and thus helps to partial out the unique proportion of variance each factor predicts. This showed that procrastination explained a significant portion of variance in PM failures ($F(3,88) = 5.58$, $p = 0.002$, $R^2 = 0.16$). Specifically, PM failures were significantly predicted by voluntary delay ($\beta = -0.28$, $t = -2.45$, $p = 0.016$) and by behavioral procrastination ($\beta = 0.38$, $t = 3.31$, $p = 0.001$) but not by observed delay ($\beta = 0.12$, $t = 1.05$, $p = 0.299$).

Different types of procrastinators: cluster analysis

Results of above analysis were in some parts contradictory to what was predicted, as they revealed a positive relation between procrastination behavior and PM failures (i.e. the longer participants postponed the procrastination task, the more PM tasks they forgot to perform), but a *negative* relation between self-reports of voluntary delay and PM failures (i.e. *less* voluntary delay reported was associated to *more* PM failures). Thus, we conducted a cluster analysis to further investigate whether our data were composed of different groups representing distinguishable participant profiles, which may provide novel insights into mechanisms that underlie procrastination and PM. In detail, cluster analysis was performed on the three variables that were revealed as being relevant in the initial regression analysis (i.e. voluntary delay, behavioral procrastination and PM failures), using the SPSS Statistics software package. Specifically, as similarity measure, we used squared Euclidean distances, which represents the predominate method to assess group similarities (for statistical guidelines on performing and reporting cluster analyses, see Clatworthy, Buick, Hankins, Weinman, & Horne, 2005). As cluster method, we used average linkage for the hierarchical agglomerative cluster analysis (again, see Clatworthy et al., 2005). A first, exploratory cluster analysis suggested one outlier data point (one participant resulting in a separate, single cluster), which was excluded from subsequent analysis. Results of the final cluster analysis suggested three separated clusters at the highest grouping level. Figure 1 depicts individual scores on the outcome measures and cluster-grouping in a three-dimensional scatterplot. Figure 2 illustrates mean scores and standard deviations of the outcome measures per cluster. Cluster 1 (henceforth labeled "non-procrastinators", $n = 34$) reported low levels of voluntary delay ($M = -0.54$, SD = 0.76), postponed the behavioral task only for a few days ($M = 6.65$, SD = 7.21) and showed few PM failures ($M = 0.05$, SD = 0.10). Cluster 2 (henceforth labeled "conscious procrastinators", $n = 25$) reported high levels of voluntary delay ($M = 1.11$, SD = 0.49), postponed the behavioral task for the most days ($M = 24.46$, SD = 8.10) and had a medium proportion of PM failures ($M = 0.22$, SD = 0.28). Cluster 3 (henceforth labeled "unconscious procrastinators", $n = 32$) reported low levels of voluntary delay

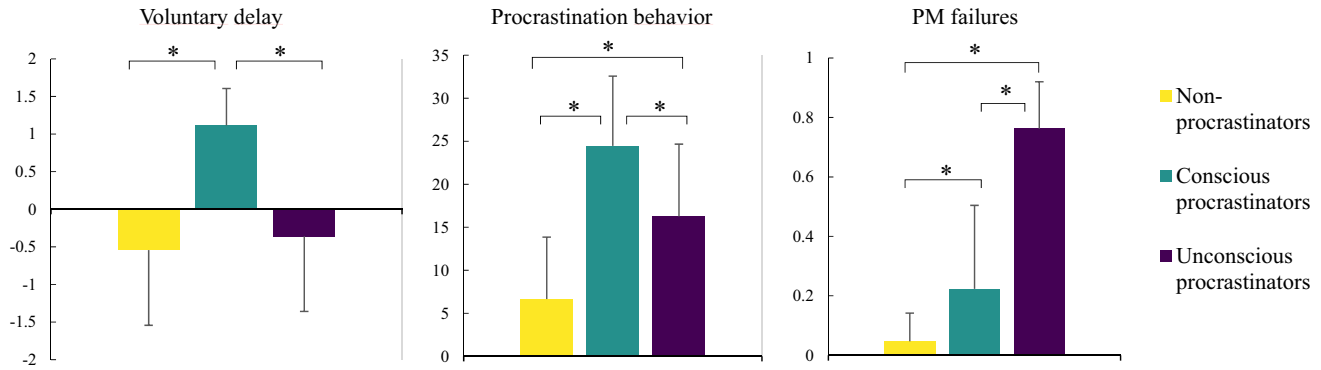

Fig. 2 Mean scores and standard deviations of voluntary delay, procrastination behavior and PM failures, separated by cluster. *t test resulted in $p < 0.001$

($M = -0.36$, SD = 0.89), but postponed the behavioral task for many days ($M = 16.26$, SD = 8.40) and had the highest proportion of PM failures ($M = 0.76$, SD = 0.16). Subsequent between-group comparisons revealed that there were significant differences in scores between the three groups on each of the three variables of interest (p's < 0.001), except between non-procrastinators and involuntary procrastinators on voluntary delay ($t(64) = 0.90$, $p = 0.367$).

Discussion

The present study is the first to examine whether procrastination constitutes a person-related factor contributing to PM failures in young adults. Overall, results show that self-reported and behavioral measures of procrastination indeed predicted PM failures. In detail, our data demonstrates that PM failures were predicted by participants' actual procrastination behavior: the longer participants delayed sending back their participation sheet, the more likely they were to commit PM failures. This indicates that individuals who tend to postpone actions for longer periods of time are less likely to perform prospective tasks in time. This is coherent with previous frameworks of PM, which suggest that PM performance decreases as the retention-interval gets longer (i.e. the time that elapses between forming an intention and executing it; e.g., Einstein et al., 2000; Kelly et al., 2013; Kliegel, Martin, McDaniel, & Einstein, 2002). Further support comes by the fact that procrastinators typically prefer to perform planned actions later rather than earlier (Svartdal et al., 2018). As a consequence, retention-intervals may often be particularly long for procrastinators, which—as our data shows—can lead to more PM failures. Our findings also cohere with Altgassen et al. (2019) who suggested a negative link between PM and procrastination. However, Altgassen et al. (2019) only used a self-reported questionnaire to assess procrastination and they focused on individuals with ADHD. The present study hereby goes one step further and corroborates these findings with an objective, behavioral measure and it extends the association of procrastination and PM for the first time to a more general, non-clinical population.

Regarding self-reports of procrastination, participants' reports of observed delay did not predict PM failures. Thereby, our data do not suggest a particular link between participants' more passive notion of 'being bad at meeting deadlines' and how often they forget to perform planned tasks. Instead, our findings reveal reports of voluntary delay as negative predictor of PM failures. A negative relation may seem surprising at first, as it suggests that the more participants indicated postponing tasks, the *less* PM failures they produced. However, looking at subsequent cluster analysis helps to better understand this somewhat counter-intuitive finding. In fact, it is possible that the overall pattern of results was (at least partially) driven by diverging subgroups among our participants. Indeed, results of the cluster analysis suggest that our sample can be divided into three different profiles of participants as a function of *if* and *how* they procrastinate and how well they perform prospective tasks, namely what we label non-procrastinators, conscious procrastinators, and unconscious procrastinators.

The first group, which we label non-procrastinators, reported low levels of voluntary delay. This was coherent with their actual behavior: on average, they postponed the procrastination task for significantly fewer days compared to the other groups. Post hoc comparisons also showed that they demonstrated significantly less PM failures compared to participants from the two other groups. Taken together, this group of individuals seems to prefer not unnecessarily delaying planned tasks (i.e. low level of self-reports of voluntary delay), which reflects on their actual behavior: they perform planned tasks earlier (i.e. few days of postponement) and they succeed at performing more of their prospective tasks (i.e. few PM failures).

The second group unveiled by the cluster analysis reported significantly higher levels of voluntary delay compared to the two other groups and they postponed the procrastination task for more days. Consequently, we labeled this group as conscious procrastinators, as they seem to be conscious about the fact they procrastinate a lot (i.e. high self-reports). As expected, they consequently also had significantly more PM failures compared to non-procrastinators. It is interesting to note that although they committed significantly more PM failures compared to the non-procrastinators, the percentage of total PM failures remained at a relatively low level (0.22 on average), which was significantly lower compared to the third group. Regarding the mechanisms that underlie the association between procrastination and PM, the profile of conscious procrastinators may indicate that although they postpone certain tasks for longer periods, they seem to be conscious of this and, therefore, remain at a functional level. As a consequence, subsequent PM failures may be relatively limited. In fact, although procrastination typically is associated with adverse outcomes, certain studies define *active procrastination* (also: active delay or purposeful delay, e.g., Choi & Moran, 2009; Chowdhury & Pychyl, 2018) as a form of procrastination which can be relatively adaptive and which does not necessarily result in negative consequences. Specifically, active procrastinators would deliberately delay particular tasks to increase pressure and motivation (Chu & Choi, 2005). They have been suggested to have good organizational skills and to schedule their activities effectively (Schraw, Wadkins, & Olafson, 2007). In this context, procrastination can represent a conscious strategy to tackle everyday tasks, sometimes even having positive effects, such as gaining time, being more productive, less undecided, and more efficient (e.g., Choi & Moran, 2009; Hensley, 2014; Schraw et al., 2007). Looking at the results of our cluster analysis, it seems plausible that conscious procrastinators in our sample had a somewhat similar profile. Although procrastination behavior was higher than in the other groups, the number of produced PM failures was still relatively low. Thereby, our findings suggest that—although they remain negative—the consequences of procrastination on PM performance may be limited, if one is conscious about ones' procrastination habits and keeps active control over it.

While the profiles of the first two procrastination groups cohere with our initial expectations (i.e., the higher the level of reported voluntary delay, the more behavioral procrastination and the more PM failures), our cluster analysis interestingly suggested a third group of participants. For this group, which we label unconscious procrastinators, there was an important incoherence regarding self-assessment and actual behavior. Specifically, results indicate that unconscious procrastinators' self-reports of voluntary delay were as low as those of non-procrastinators, whereas their actual procrastination behavior was significantly higher compared to non-procrastinators. Importantly, the number of PM failures for unconscious procrastinators was by far the highest of all groups (non-procrastinators = 0.05, conscious procrastinators = 0.22, unconscious procrastinators = 0.76). It seems that although they procrastinate for relatively long periods of time and forget an important number of prospective intentions, unconscious procrastinators were not aware of having difficulties to meet deadlines or of struggling to manage their personal goals (i.e. low level of self-reports). In combination with the pattern of results for conscious procrastinators, these findings may be particularly interesting and conceptually relevant. Specifically, our data suggest that the relation between procrastination and PM is influenced by how aware an individual is of their procrastination habits. It seems that if one is conscious about procrastination, the negative impact of procrastination on performing a real-life PM task may be limited. It could be that this awareness allows individuals to set up strategies to "limit the damages" and, therefore, to still remember a relatively large proportion of their prospective intentions in real-life. In contrast, consequences of procrastination seem more severe for individuals who are not conscious of their procrastination habits. In these cases, individuals may—unawarely so—postpone tasks for longer periods and thereby increase the number of forgotten PM tasks.

In terms of underlying cognitive processes, the missing awareness of procrastination behavior could be related to participants' metacognition (i.e. awareness and understanding of one's own thought processes). To have an accurate judgement of metacognition (e.g., knowing that "I tend to postpone tasks for too long"), one in a first step needs to precisely monitor their behavior (e.g., reflecting on "if I continue at this pace, will a mange to finish in time?"). Such monitoring processes then determine *whether* and *which* control strategies one implements (see monitoring-control circle, Nelson & Narens, 1990). As unconscious procrastinators fail to assess their own procrastination accurately, they might set up inappropriate control strategies, which, in turn, can lead to PM failures (e.g,. Rummel & Meiser, 2013). Indeed, previous studies have stablished a link between PM failures and metacognitive problems (for a recent review, see Kuhlmann, 2019), and the present results seem to further support this relationship.

Finally, the present findings highlight the importance of assessing procrastination both with subjective and with objective measures. Combining both types of measurement provided new theoretical insights on the mechanisms that underlie the relation between procrastination and PM failures, which could not have been uncovered by studying each aspect separately. Specifically, our data show that discrepancies between subjective and objective evaluation of procrastination even had a more negative impact on participants'

PM performance than high scores on both procrastination measures per se.

Although the present study provides first insights into the connections between procrastination and PM, future studies will have to examine this relation and its underlying mechanisms in more detail. For example, studies will have to explore how exactly postponement and longer retention-intervals can lead to PM failures. It is possible that this purely relates to memory abilities (e.g., extended postponement leading to forgetting the intention) or that additional mechanisms are involved (e.g., insufficient metacognition leading to incoherent planning and inaccurate monitoring of the intention). In this context, we also point out that the present study design and analyses do ultimately not allow to exclude reverse causality. Indeed, although we argue that procrastination can lead to PM failures, Altgassen et al. (2019) suggest that participants' PM abilities contribute to procrastination. Future studies applying different designs and statistical methods (e.g., longitudinal studies and cross-lagged modelling) will have to re-examine the causality between procrastination and PM in more detail.

In addition, as this is the first study to examine whether procrastination can lead to PM failures, a final limitation is that these findings remain somewhat preliminary at this point. Although we argue that one group of participants consisted of individuals who were not sufficiently aware that they procrastinate (i.e. "unconscious procrastinators"), an alternative interpretation could be that these individuals typically do not procrastinate much (hence the low self-reported procrastination), but that they exceptionally did so in our study, for example because they were particularly busy during that period.[2] To minimize this bias, we restricted our target sample to second-year bachelor students, because they have a very homogenous academic schedule (i.e. total course credits per semester and number/variety of available courses are pre-defined and limited). In contrast to other, more heterogeneous populations, participants' academic busyness should therefore have been relatively comparable across the sample. Nevertheless, it is still possible that the group labeled "unconscious procrastinators" was particularly busy due to reasons not related to their academic life. The fact that the "unconscious procrastinators" postponed the task for significantly fewer days compared to the "conscious procrastinators" would support this alternative interpretation. Thus, future studies will have to replicate our findings and should further examine the role of participants' busyness in more detail, for example by assessing or by controlling for inter-individual differences in busyness.

Finally, future studies will also have to evaluate how the newly gained knowledge can be incorporated into potential interventions. For example, we initially presented implementation intentions as strategy that was used to reduce procrastination and to increase PM performance. However, previous studies found mixed results regarding their efficiency (e.g., Gustavson & Miyake, 2017; Owens et al., 2008). In view of our novel findings, for individuals that tend to procrastinate, rather than learning planning strategies like "when event X occurs, then I will do action Y", it may prove more beneficial to help individuals in a first step to realize that they procrastinate, and that this has negative consequences on their real-life outcomes. Similarly, it seems essential to better understand which strategies conscious procrastinators use to plan tasks, to manage their time and to succeed at prospective tasks to then propose those strategies to unconscious procrastinators.

In conclusion, the current study is one of the first to explore the link between procrastination and PM and indicates that procrastination represents a novel factor contributing to PM failures. On one hand, our results show that less procrastination is generally associated to better PM performance. On the other hand, using cluster analysis on self-reports and behavioral measures also gives new insights into how procrastination may differentially contribute to PM failures. Specifically, being aware of one's procrastination habits limits the negative influence of procrastination on PM. In contrast, the negative influence of procrastination on PM seems particularly strong if one is not aware of their procrastination habits, leading to an important number of PM failures. Finally, our data also demonstrates that it is crucial to assess procrastination via subjective and objective measures to get a more complete picture of different underlying mechanisms.

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Data availability statement The datasets generated and analyzed for the current study are not publicly available because participant consent forms did not include authorization for public data sharing. However, data are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of Interest All authors declare that they have no conflict of interest.

[2] We thank an anonymous reviewer for suggesting this possibility.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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