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Creativity as It Unfolds: An Examination of Temporality in the Creative Process

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ABSTRACT
Scholars view the creative process as a sequence of activities (e.g. problem construction, information search, idea generation, and idea development) that unfolds over time. This implies that time plays an important role in creativity. Unfortunately, however, the field lacks clear and explicit propositions about the temporal aspects of the creative process and lacks suitable methodology to examine this process in detail. In this paper, we firstly outline two broad perspectives on the creative process, the linear and iterative perspectives, and translate their implicit theories of time into temporal propositions regarding the duration, frequency, timing, and sequencing of creative process activities. Secondly, we develop and use an experimental framework that enables us to test these propositions, and offer some initial insights into how the creative process unfolds. These analyses suggest 1) that some people followed a more linear approach to creativity, whereas others behaved more in line with the iterative approach; 2) that those who followed the iterative approach generated more original solutions; and 3) this difference mainly occurred because people who followed the iterative approach spent more time on idea selection and development.

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Introduction

Time is a central factor in organizational life and human behavior, and several scholars have argued that time should be more strongly incorporated in our theorizing and research (Aguinis & Bakker, 2021; Ancona, Goodman, Lawrence, & Tushman, 2001; George & Jones, 2000). This also applies to the field of creativity, which is concerned with the generation of ideas that are both novel and useful (Amabile, 1983). Creativity is a process that involves different activities such as problem construction, information search and encoding, idea generation, and idea selection and elaboration (Finke, Ward, & Smith, 1992; Fürst, Ghisletta, & Lubart, 2017; Mumford, Medeiros, & Partlow, 2012; Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991; Reiter-Palmon & Illies, 2004; Watts, Steele, Medeiros, & Mumford, 2019). Because individuals are expected to engage in a sequence of all (or some) of these activities to produce creative outcomes, this necessarily implies an important role of time (see also Lubart, 2001; Runco, 2019; Steele, 2019).

Over the years, several models of creativity have been suggested that take the role of time into account (e.g., Amabile, 1983, Harvey, 2014; Perry-Smith & Mannucci, 2017). More specifically, these models consider *temporality*, which refers to the role of time in (the sequencing of) specific processes (such as creative processes). On a general level, temporal models of creativity can be classified into two broad categories: more linear, stage-based models (Harms, Reiter-Palmon, & Derrick, 2020; Mumford, Medeiros, & Partlow, 2012; Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991; Reiter-Palmon & Illies, 2004; Watts, Steele, Medeiros, & Mumford, 2019) and more dynamic, iterative models (Bink & Marsh, 2000; Finke, Ward, & Smith, 1992; Fürst, Ghisletta, & Lubart, 2017). These models offer (sometimes differing) insights into several important questions, such as which activities (e.g., problem construction or idea development) are more important for achieving creative success, whether and to what degree the creative process is ordered or chaotic, and when (e.g., early or late in the process) activities should take place (see also Lubart, 2001). Empirical evidence, however, does not paint a clear picture, with some studies supporting one prediction (e.g., problem construction is the most important activity: Ma, 2009) and others seemingly contradicting this (e.g., idea development is more important; Watts, Steele, Medeiros, & Mumford, 2019). This is problematic as it limits our understanding of how a successful creative process should unfold over time.

We propose that two fundamental issues hinder our understanding of the temporal aspects of the creative

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process, namely (1) the lack of clear and explicit conceptualizations of temporality in theorizing about the creative process, and (2) the lack of suitable methodology to measure temporal aspects of the creative process. Firstly, when developing an understanding of the role of time or temporality in any field, it is important to include clear and explicit conceptualizations of them (Aguinis & Bakker, 2021; McKay & Gutworth, 2021). Although the theoretical work on the creative process is quite rich, assumptions about the role of time and temporality in the creative process have largely remained implicit (Bink & Marsh, 2000; Finke, Ward, & Smith, 1992; Mumford, Medeiros, & Partlow, 2012; Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991; Reiter-Palmon & Illies, 2004; Watts, Steele, Medeiros, & Mumford, 2019). There are several conceptualizations of time as related to creativity (e.g., polychronicity: Madjar & Oldham, 2006; Zeitgeist:; Sternberg, 2018), but in this paper we draw on the taxonomy of temporality from Aguinis and Bakker (2021). We use this taxonomy to translate implicit ideas about *temporal* aspects in the creative process into explicit propositions, specifically regarding the (1) *duration*, (2) *timing*, (3) *frequency*, and (4) *sequencing* of creative activities. In doing so, we do not aim to examine all dimensions and expressions of temporality in relation to the creative process. Rather, we apply this taxonomy of temporality (not "time" in general) to more linear and more iterative models of the creative process to derive clear propositions on how these temporal dimensions may relate to creative outcomes.[1]

Secondly, progress has been hindered by a lack of suitable methodology. That is, retrospective research found that individuals have difficulty recalling the exact sequence of activities (Botella & Lubart, 2019), laboratory research has focused on isolated effects of one specific activity (Mumford, Baughman, Supinski, & Maher, 1996; Mumford, Baughman, Threlfall, Supinski, & Costanza, 1996; Reiter-Palmon, Mumford, O'Connor-Boes, & Runco, 1997), and field research has only assessed the overall engagement in creative processes (Mahmood, Uddin, & Fan, 2019; Zhang & Bartol, 2010). We therefore need a new paradigm to systematically explore the temporal dimensions of the creative process and their relationship with creative outcomes. The exploratory experimental method that we developed and describe in this paper allows us to examine the creative process in a fine-grained way as it dynamically unfolds over time.

The goals of this paper are threefold. First, we build on Aguinis and Bakker (2021) to develop propositions on the role of temporality in the creative process. Second, we introduce and develop a new methodological paradigm to examine temporal aspects of the creative process. Third, we use this new approach to provide explorative insights into the way individuals structure their creative process and what consequences this has for creative outcomes. We emphasize that these results should be seen as an exploration of how the creative process may unfold over time.

Theoretical framework

Models of the creative process

Over the years, different authors have suggested models of temporality in the creative process. Wallas (1926), for example, suggested his classic model of insight problem solving that consists of four phases: preparation, incubation, illumination, and verification. Evolutionary models of creativity (Campbell, 1960; Simonton, 1999) assume that creativity involves an iterative process of blind (or quasi-random) variation (creating ideas) and selective retention of the most promising ideas. Subsequently, these retained ideas can be built on to generate more ideas. Amabile's (1983) influential model suggests that the creative process consists of five successive steps: problem presentation, preparation, response generation, response validation, and outcome. Importantly, her model also contains iterative aspects: when in the outcome stage reasonable progress has been made, the creator is presumed to return to an earlier stage (otherwise the process is ended as either successful or unsuccessful). Amabile further assumed that different factors, such as intrinsic motivation, domain knowledge, and creativity skills, exert their effects on different stages of the process. In a more recent model of the "idea journey," Perry-Smith and Mannucci (2017) proposed four stages of innovation: idea generation, idea elaboration, idea championing, and idea implementation. Like Amabile, they assumed that different variables would have differential effects during different stages, although Perry-Smith and Mannucci focused specifically on social network effects and included later-stage processes of idea championing and implementation. In sum, a number of models assume that creativity consists of different stages that individuals move through to produce creative outcomes.

These and other models of the creative process usually differ in the extent to which they (implicitly or explicitly) emphasize one of two perspectives: the (linear) stage-based perspective and the (dynamic) iterative perspective[2] (Fürst, Ghisletta, & Lubart, 2017; Rosing et al., 2018); see also Bink and Marsh (2000); Finke, Ward, and Smith (1992); Mumford, Mobley, Reiter-Palmon, Uhlman, and Doares (1991), Mumford, Medeiros, and Partlow (2012); Reiter-Palmon and Illies (2004). The linear perspective is characterized by stage-based models that consist of a number of distinct step-by-step stages that individuals systematically (e.g., in a specific order) go through to produce creative outcomes (Mumford, Medeiros, & Partlow, 2012; Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991; Reiter-Palmon & Illies, 2004). Although there are several different models, most scholars agree that the central creative process activities include problem construction, information search and encoding, idea generation, and idea selection and elaboration (Harms, Reiter-Palmon, & Derrick, 2020; Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991; Reiter-Palmon & Illies, 2004; Watts, Steele, Medeiros, & Mumford, 2019). Problem construction constitutes the identification of the goals, procedures, and information required to solve the problem; Information search involves connecting, integrating, and encoding information; idea generation is the production of alternative solutions or outcomes; idea selection and elaboration is the evaluation and development of generated ideas based on certain criteria or standards (Mumford, Lonergan, & Scott, 2002; Watts, Steele, Medeiros, & Mumford, 2019).

The iterative perspective assumes that individuals apply different creative activities in an alternating fashion during the creative process, which allows them to progressively develop a vague idea into a thoroughly developed creative final product (e.g., Bink & Marsh, 2000; Finke, Ward, & Smith, 1992; Fürst, Ghisletta, & Lubart, 2017; Lubart, 2001). Given that the literature consists of multiple, similar iterative models (Basadur, 1995; Finke, Ward, & Smith, 1992; Runco & Chand, 1995), we rely on Bink and Marsh (2000), who proposed a synthesis of these models. They suggested that the creative process consists of *generation* and *selection* activities. Generation activities involve the recruitment of task-relevant information, the synthesis of this information, and the production of ideas and original associations. As such, generation shows conceptual overlap with the problem construction, information search and encoding, and idea generation processes from the linear approach. Selection activities refer to the evaluation, selection, and development of ideas, and selection conceptually overlaps with the construct of idea selection and elaboration from the linear approach. In these iterative models, creative activities are assumed to be applied in an alternating fashion during the creative process, thereby leading to creative outcomes (Bink & Marsh, 2000; Fürst, Ghisletta, & Lubart, 2017; Lubart, 2001).

The distinction between the two approaches should be seen as gradual rather than black-and-white. Thus, linear models put more emphasis on the progression through different stages, but do not deny that the creative process will involve iterative aspects. Similarly, iterative models emphasize the dynamic nature of the process, but do not deny that there will be some order in these processes. Our aim is therefore not so much to find out which of these two approaches is more valid, but rather to derive testable propositions for both and to develop methodology that allows us to evaluate the degree to which these propositions are supported.

Temporality in the creative process

Temporality and creativity are connected, not only because time is an important resource for creativity (Mednick, 1962; Runco, 2004), but also because the subjective experience of time may influence creativity (Mainemelis, 2002). For instance, Antes and Mumford (2009) found that individuals' temporal orientation (past, present, future) did not affect the quality (e.g., originality) of their creative performance, but did affect the execution of specific creative processes. Other research has found that the experience of timelessness (Mainemelis, 2001) is associated with increased engagement in creative processes (Ferreira, 2021). However, although creative processes and time are innately linked, there are surprisingly little systematic investigations on how exactly creative processes unfold over time.

Developing an understanding of the role of time in any field remains challenging as long as time is not conceptualized unambiguously and explicitly (Aguinis & Bakker, 2021; McKay & Gutworth, 2021). There are different ways to conceptualize time, such as subjective time (Allman, Teki, Griffiths, & Meck, 2014), polychronicity (Madjar & Oldham, 2006) and Zeitgeist (Sternberg, 2018). We will use the conceptualization of temporality by Aguinis and Bakker (2021), who distinguished four ways to define temporality of processes conceptually: (1) the *duration* or the temporal length of an activity, (2) the *frequency* or the number of times an activity occurs over a specific period, (3) the *timing* or the when of (the onset or offset of) an activity, and (4) the *sequence* or the temporal ordering of activities on a timeline.

To relate these different conceptualizations of temporality to creativity requires assumptions about the creative process. Despite their differences, prior conceptualizations seem to share three important assumptions. Firstly, there is consensus that the creative process is composed of multiple activities, and in this paper, we focus on problem construction, information search and encoding, idea generation, and idea selection and elaboration. Secondly, these activities are considered interdependent, which means that the outcomes of one activity serve as input for other activities (Bink & Marsh, 2000; Reiter-Palmon & Illies, 2004). Thirdly, engaging in these activities is considered time-consuming and cognitively demanding (Finke, Ward, & Smith, 1992; Reiter-Palmon & Illies, 2004). Taken together, we can define the creative process as individuals' engagement in a sequence of distinct and cognitively demanding activities related to creativity, regardless of whether the outcome itself is considered creative (Drazin, Glynn, & Kazanjian, 1999; Lubart, 2001; Reiter-Palmon & Illies, 2004; Zhang & Bartol, 2010).

Duration refers to the amount of time that individuals spend on developing a creative outcome. Given that the creative process consists of distinct activities (Bink & Marsh, 2000; Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991) that are cognitively demanding (e.g. Reiter-Palmon & Illies, 2004) and that cognitive resources are scarce (Hobfoll, Halbesleben, Neveu, & Westman, 2018), it follows that individuals should spend most of their time on the activities that are most important in the development of creative outcomes. Thus, looking at the *duration* of engagement in specific activities is central in answering the question which activity is most important for the generation of creative outcomes.

Frequency refers to how many times individuals engage in a particular activity within a particular time interval (e.g., once or multiple times, with other activities performed in between). Examining frequency provides an answer to the question raised by Lubart (2001) to what extent the creative process is dynamic or recursive, and how this influences the creativity of outcomes. A creative process that is characterized by a high frequency of engagement in different activities is more dynamic or chaotic, because people return often to earlier activities, whereas a process with a low frequency of engagement in different activities can be considered more static or linear (e.g., every activity is performed only once in a linear sequence).

Timing refers to the moment *when* individuals spend time on specific activities (i.e., placement of an activity on a timeline). Looking at the timing of certain activities relates to the question when individuals should start (onset) or stop (offset) with a specific activity. *Sequencing* refers to the specific temporal ordering in which individuals engage in activities. Sequencing adds a layer of complexity to the construct of timing, because timing does not consider what happens before and after engagement in a specific activity. Looking at the sequence of the creative process involves examining in which order individuals engage in specific activities, and thereby can be used to examine the interdependencies of these creative activities. According to Lubart (2001), it is possible that creative activities can be sequenced in multiple ways, and still yield creative outcomes. Consequently, he suggested that research should devote attention to whether specific sequences lead to highly creative products.

So far, the creative process literature has not systematically analyzed how duration, frequency, timing, and sequencing of creative activities relate to creative outcomes (Bink & Marsh, 2000; Finke, Ward, & Smith, 1992; Mumford, Medeiros, & Partlow, 2012; Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991; Reiter-Palmon & Illies, 2004). In what follows, we develop explicit temporal propositions regarding the creative process for both the linear and iterative perspective. Table 1 shows the temporal propositions that we will investigate in this paper, based on the linear and iterative perspectives.

Before developing these propositions, it is important to note that previous research has not consistently supported one (set of) prediction(s) over another. For example, and consistent with a linear approach, Ma (2009) meta-analytically found that engagement in problem construction and information search and encoding were more strongly correlated with creative outcomes than other activities (cf. proposition 1a). Similarly, Scott, Leritz, and Mumford (2004) found

Table 1. Overview of temporal propositions for both perspectives.

	Linear perspective	Iterative perspective
Duration	P1a: Problem construction and information search and encoding are most strongly related to creativity	P2a: Idea selection and elaboration is most strongly related to creativity
Timing	P1b: Timing of the onset of idea generation and idea selection and elaboration is positively related to creativity	P2b: Timing of the onset of idea selection and elaboration is negatively related to creativity
Frequency	P1c: Frequency of engaging in creative processes is negatively related to creativity	P2c1: Frequency of engaging in creative processes is positively related to creativityP2c2: Frequency of engaging in creative processes is curvilinearly related to creativity
Sequence	P1d: The proportion of switches between non-adjacent process activities is negatively related to creativity	P2d: The proportion of switches between non-adjacent process activities is positively related to creativity

that training focused on problem construction yielded larger effect sizes on creativity than training focused on other activities. However, other findings are in line with the iterative approach. For example, Watts, Steele, Medeiros, and Mumford (2019) found that the originality of initially generated ideas was not related to the creativity of a final outcome, but that the creativity of the final solution was strongly impacted by idea refinement activities (consistent with proposition 2a). Furthermore, in support of the idea that the onset of idea selection activities should be early (cf. Proposition 2b), Lubart (2009) found in a creative writing task that participants who were instructed to evaluate their work early on, compared to participants who did not receive this instruction, wrote stories that were higher in creativity (see also Fürst, Ghisletta, & Lubart, 2017). Moreover, Pringle and Sowden (2017) found that switching between associative processes (generation) and analytic processes (evaluation) was positively related to the creativity of the final design in a garden design task, suggesting that performing these activities multiple times is beneficial (see also Fürst, Ghisletta, & Lubart, 2012, 2017; consistent with proposition 2c). Taken together, it appears that prior research is not fully able to answer which temporal propositions (i.e., of the more linear or more iterative perspective) are better supported empirically.

Linear stage-based models

The linear approach is based on two assumptions that enable us to derive temporal propositions about effects of duration, frequency, timing, and sequencing of creative activities. Firstly, individuals are supposed to engage in activities in a specific order, because each activity yields an output that serves as an input for the next process. As such, early-stage activities (problem construction and information search and encoding) serve as a foundation for successful execution of later-stage activities (idea generation and idea selection and elaboration). Secondly, switching back and forth between activities is ineffective, because switching depletes cognitive resources and implies that earlier activities were deficient.

The assumption that early-stage activities serve as a foundation for successful execution of later-stage activities has implications for the effects of duration and timing of these activities. Scholars following a linear approach propose that the more time individuals spend on problem construction, the more diverse and richer the constructed problem is. This, in turn, leads to more diverse and broad information search and encoding, which in turn serves as the source from which ideas are generated (Reiter-Palmon & Illies, 2004). For example, Mumford, Mobley, Reiter-Palmon, Uhlman, and Doares (1991) argued that the success in later stages of the creative process is contingent on adequate up-front work, implying that insufficient problem construction and/or inadequate information search and encoding will hinder individuals' idea generation. Thus:

Proposition 1a: The duration of problem construction and information search and encoding is more strongly positively related to creativity than the duration of other activities.

The notion that success in idea generation and idea selection and elaboration processes strongly relies on adequate engagement in problem construction and information search and encoding also suggests that idea generation and idea selection and elaboration will not be effective if individuals have not spent enough time on constructing the problem and searching for information first. Therefore, it follows that:

Proposition 1b: The onset (timing of first engagement) of idea generation, and idea selection and elaboration is positively related to creativity: starting these activities later is associated with higher creativity.

The assumption of the linear perspective that switching between creative activities is ineffective and inefficient has implications for the effects of frequency and sequencing of activities. According to the linear approach, individuals switch from one stage or activity of the creative process to the next after that activity has been successfully executed. Prematurely stopping an activity hinders successful execution of later-stage activities and should therefore hinder creativity. In addition, although the linear perspective acknowledges the possibility of cycling back to earlier stages, it is suggested from a cognitive efficiency perspective (Hobfoll, Halbesleben, Neveu, & Westman, 2018) that this only happens when individuals notice a deficiency in their earlier creative activities (Mumford, Medeiros, & Partlow, 2012; Reiter-Palmon & Illies, 2004). Because switching between activities requires cognitive resources, it follows that switching between processes is a waste of cognitive resources and therefore:

Proposition 1c The frequency of engagement in different activities is negatively related to creativity.

Although the linear perspective suggests that switching is negatively related to creativity, it could be that some switches are more detrimental to creativity than others: certain switches may contribute to creativity (are functional), whereas others may be detrimental (are dysfunctional). The notion that early-stage activities serve as foundation for late-stage activities (Reiter-Palmon & Illies, 2004) suggests that switching to an adjacent activity can be considered functional, whereas skipping activities would be inefficient. In addition, individuals may move back to the activity directly prior to the current creative activity to repair any deficiencies or errors they encounter (Mumford, Medeiros, & Partlow, 2012; Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991). This may also be functional, because it enables the individual to eventually move on in the creative process. However, skipping steps backwards to non-adjacent activities (i.e. switching from idea selection to information search and encoding or problem construction) would be especially inefficient, because it costs cognitive resources (Hobfoll, Halbesleben, Neveu, & Westman, 2018; Mumford, Reiter-Palmon, & Redmond, 1994), while it does not directly contribute to resolving deficiencies in the creative process. As such, we derived the proposition:

Proposition 1d: The proportion of switches between non-adjacent activities (as compared to all switches among activities) is negatively related to creativity.

Dynamic iterative models

The most important features of iterative models are: (1) Given that initial ideas need to be selected, and often require further development, late-stage activities focused on selection and elaboration of ideas (Bink & Marsh, 2000; Lubart, 2009) are very important to creative outcomes; and (2) creativity results from the dynamic interplay between creative activities, and there is no fixed order in which individuals should engage in these activities; rather, switching between activities is both inevitable and necessary.

The assumption that idea selection and elaboration are especially important for creative outcomes has implications for the duration and timing of activities. Selection activities are considered important because initial ideas that result from generation activities usually are not final products (Bink & Marsh, 2000; Lubart, 2009; Ward, 2004). That is, generation activities produce building blocks and candidate ideas for a final solution, while selection activities (including evaluation, elaboration, and development) form those building blocks into a final product. For example, Perry-Smith and Mannucci (2017) suggested that during idea elaboration, the idea transforms from a vague concept into a tangible outcome, that may vary in creativity. Indeed, Lubart (2009) suggested that the most creative individuals devote relatively more time to selection activities. Therefore, it follows that:

Proposition 2a: The duration of idea selection and elaboration is more strongly related to creativity than the duration of other activities.

Bink and Marsh (2000) suggest that selection activities also serve a meta-cognitive function: selection activities are utilized to ensure that initial ideas (or "pre-inventive structures") that are retained for further development and refinement can in fact be used to build a final creative solution. Thus, one of the central functions of selection activities is retaining or discarding initially generated ideas (Bink & Marsh, 2000; Fürst, Ghisletta, & Lubart, 2017; Lubart, 2009; Ward, 2004). Starting early on with idea selection is considered crucial, because this enables creators to drop, modify, or reorient initial ideas in such a manner that the pre-inventive ideas that are retained for further elaboration contribute to the creativity of the final outcome. In contrast, it is suggested that individuals who postpone idea selection will get more attached to their ideas, and will have a harder time discarding unoriginal ideas (Lubart, 2009). Therefore, it follows that:

Proposition 2b: A later onset of idea selection and elaboration is negatively related to creativity, while starting this activity early is associated with higher creativity.

The assumption that creative outcomes arise from a dynamic interplay between generation and selection activities (Bink & Marsh, 2000; Finke, Ward, & Smith, 1992; Pringle & Sowden, 2017) has implications for the frequency and sequencing of activities. More specifically, the iterative perspective suggests that iterations between generation and selection enable individuals to progressively develop a vague and incomplete idea into a well-developed creative final solution (Bink & Marsh, 2000; Fürst, Ghisletta, & Lubart, 2017; Pringle & Sowden, 2017). This means that the relation between frequency and creativity may be positive, although it is also possible that some optimum exists after which a further increase in frequency no longer has positive effects. Therefore, it follows that:

Proposition 2c1: The relationship between the frequency of engaging in different activities and creativity is positive.

Proposition 2c2: The relationship between the frequency of engaging in different activities and creativity follows an inverted U-shape.

According to the iterative perspective, the nature of real-world creativity is characterized by unpredictability, surprises and setbacks (Bink & Marsh, 2000; Fürst, Ghisletta, & Lubart, 2017; Lubart, 2001). To deal with these setbacks, individuals must switch between different types of creative activities as demanded by the task and not necessarily in a predefined order (Kaufman, 2011; Rosing et al., 2018; Runco & Chand, 1995). Since these setbacks might require engagement in any of the creative activities, it is unlikely that the creative process follows a specific order. Thus, acting completely linear signals a failure to recognize what is required, therefore:

Proposition 2d: The proportion of switches between non-adjacent creative activities (as compared to all switches among activities) is positively related to creativity.

The present study

To date, few existing methodological frameworks are fully equipped to address our research questions, for three reasons. Firstly, most of the studies that have examined longitudinal aspects of the creative process have used a suboptimal timeframe. To capture the dynamic and sometimes ephemeral aspects of the creative process, a micro-longitudinal design is required, with repeated measurements on short time intervals (e.g., seconds). Studies to date, however, have either taken days (Fürst, Ghisletta, & Lubart, 2012) or minutes (Fürst, Ghisletta, & Lubart, 2017) as measurement unit. Although these studies are informative, they are not able to capture the full dynamics of the process.

Secondly, to capture the creative process as it occurs naturally, we must aim to measure processes unobtrusively. Individuals should be able to move freely through the creative process, without noticing that their behavior is being manipulated or monitored (Reiter-Palmon & Robinson, 2009). Various studies that have measured engagement in multiple creative activities, however, have either manipulated degree of engagement in specific activities and/or fixed the order in which individuals engaged in these activities (Friedrich & Mumford, 2009; Fürst, Ghisletta, & Lubart, 2017; Harms, Reiter-Palmon, & Derrick, 2020; Medeiros, Partlow, & Mumford, 2014). Although these studies are insightful, they do not inform us on what the creative process looks like as it naturally unfolds over time.

Thirdly, the studies that have not manipulated engagement in specific activities have either relied on self-report measures (e.g. Botella & Lubart, 2019; Botella, Zenasni, & Lubart, 2011; Fürst, Ghisletta, & Lubart, 2012) or on think-aloud protocols (Boldt, 2019; Pringle & Sowden, 2017). Both measurements are likely to contain noise. Thus, studies show that individuals have difficulty recalling the exact sequence of their engagement in specific activities (Botella & Lubart, 2019), and think-aloud protocols rely on participants' spontaneous actions or vocalization of internal processes, which participants may not be capable of (Rubenstein, Callan, Neumeister, Ridgley, & Hernández Finch, 2020).

To get a detailed view of the temporal aspects of the creative process, we thus used a micro-longitudinal design, in which engagement in problem construction, information search and encoding, idea generation, and idea selection and elaboration was measured from second to second. In addition, we aimed for unobtrusive and objective measurement by designing an experimental environment in which individuals could freely move between activities, and by monitoring engagement in specific activities without the participant's awareness. We accomplished this by creating a digital environment, in which participants were requested to solve an ill-defined problem, and in which they could freely navigate among different creative activities that were clearly labeled or related to problem construction, information search and encoding, idea generation, and idea selection and elaboration.

Method

Participants

Participants were 206 business students (78 female, 128 male) from a university in The Netherlands. All participants were informed about the general purpose of the study and gave written consent. Their average age was 21.5 years (*SD* = 2.27). A brief description of the study was posted on the university website, and in exchange for participation students could opt for financial compensation (€ 8,00) or course credits. Ethical approval has been obtained from the Institutional Review Board, and informed consent was obtained from all participants.

Procedure

Participants worked in a private cubicle with a single computer. At the start, instructions on the screen stated that participants were about to work in a digital environment in which they had to generate a creative solution to an important societal problem. The application that participants used was coded using Authorware 7.02. Before starting with the actual task, participants were guided through a test version of the digital environment in which they later had to complete the experimental task. This test environment, consisting of five pages among which participants could freely switch, was a replica of the actual task environment. Instead of the task-content, however, the five pages contained a description of the content that would be present on this page during the experiment and instructions about how participants could interact with this page.

After going through the test version, participants were directed to the actual task environment. In this environment, the first page – the instruction page – showed an e-mail from their supervisor, Mario, director of Creative Consultancy BV. In the e-mail, Mario asked participants to work on some of the main problems that the educational system in the Netherlands faces. Specifically, he asked participants to (1) define what they think the most important problem of the educational system is, (2) generate a list with ideas that might help to solve the problem, and (3) elaborate on one final solution, that had to be creative. Note that although individuals were able to switch back to this page too, this activity was excluded from further analyses since it does not represent an element of the creative process.

The second page was the information page, which measured *information search and encoding*. It consisted of 32 folders with information related to the problem. Participants were instructed that they were free to access as many folders as they wanted, and that they could do so in any order. To increase intentional browsing, all folders had a brief title hinting toward their content. For how long (duration in seconds), how often (frequency in numbers), and when (timing of onset and sequence) the information page was visited was measured and used to operationalize various temporal aspects of information search and encoding.

The third page was the problem page, which measured *problem construction*. It presented participants with a text field, in which they were instructed to define their view on the educational problem and to write down all the elements of the problem. Specifically, the instructions asked participants to go to this page and write something down whenever they thought of something related to problem definition. Visits to this page were used to compute the duration, frequency, timing, and sequence of problem construction activities.

The fourth page was the idea page, and measured *idea generation*. It also contained a text field, in which participants had to write down all the ideas they came up with that might help in solving the problem. Participants were instructed to write down these ideas whenever they thought of something. Visits to this page were used to measure the duration, frequency, timing, and sequence of idea generation activities.

The fifth page was the solution page, and measured *idea selection and elaboration*. It contained a text field, in which participants were asked to come up with one final solution. It was stated explicitly that this final solution had to be creative. Visits to this page were used to operationalize the duration, frequency, timing, and sequence of idea selection and elaboration activities.

During the experiment, participants could freely navigate among the pages in any order and at any moment they wanted, using a navigation panel that was always present at the bottom of the screen. Each specific page was depicted on the navigation panel with a button containing the corresponding page name. Furthermore, the task was not limited by time constraints. Whenever participants felt they completed the task, they could press a “send” button that was visible on the solution page. After completing the task, participants completed a survey consisting of task-related state measures and individual-differences measures.

Measures

Creative process engagement

Throughout the task, we tracked participants’ activity on pages in the experimental paradigm, and based on this we computed measures of engagement in the creative process. Duration of a specific activity was operationalized as the total amount of time spent on the corresponding page. Frequency was measured as the total number of visits to a certain page (excluding visits that were shorter than one second, assuming that these visits were not intentional). Timing was operationalized as the onset and offset of specific activities. Onset was operationalized as the first visit to a page that lasted more than one second, and offset as the last visit that lasted more than one second. Sequence was operationalized by first counting all process switches (excluding switches shorter than one second), and then establishing the number of adjacent and non-adjacent switches. Non-adjacent switches involve problem construction↔idea generation, problem construction↔idea selection and evaluation, information search and encoding↔idea selection and evaluation. All non-adjacent switches were summed and divided by the total number of switches.

Creativity of final solution

Two independent judges rated the *novelty and usefulness* of the final solutions. For novelty, judges indicated to what extent the solution was novel, ranging from 1 ("Not at all") to 5 ("Extremely"). For usefulness, judges indicated to what extent the proposed solution would contribute to resolving the problem, ranging from 1 ("Not at all") to 5 ("To a large extent"). The two judges first rated fifteen responses, which were then compared. All discrepancies of two or more scale points were discussed, aiming to discover the considerations that were used while rating, and reaching agreement on which considerations were most important. Afterwards, the rest of the data was coded. Interrater agreement for novelty and usefulness were .85 and .74, respectively.

Results

Data exclusions

Following best practice recommendations (Aguinis et al., 2013), we first examined potential data exclusions. Firstly, seven cases were excluded because of errors in the experimental procedures: four individuals left the solution page blank, one did not use the idea generation page at all, one participant indicated that all ideas reported on the solution page had disappeared at some point, and one participant left the lab because of a bathroom break. Secondly, we examined potential multivariate outliers in each of our analyses, following the procedures of Aguinis et al. (2013). Since not all analyses use the same set of variables, we decided to be stringent by only excluding cases that were considered outliers in all analyses. Specifically, using Mahalanobis distance, and a Chi-square distribution to examine the significance of the Mahalanobis distance for each participant across the seven different models that we test below, we found 30 candidate outliers, but only two were consistent outliers in all models, and these were excluded. For the analyses, we thus used a sample of $N = 197$.

Data analytic strategy

Before testing the propositions of the more linear and the more iterative models, we aimed to provide more general insights into how our participants approached the task. To this end, we first report descriptive statistics, which provide a first picture of how participants behaved on average. We then performed a technique that has, to the best of our knowledge, not been used previously in the study of creative processes, namely sequence analysis (Abbott, 1995). Using sequence analysis, it is possible to identify different clusters of participants, who differ in how they order their task activities over time. This makes it possible to examine whether some participants behaved more in line with the linear perspective, whereas others behaved more in line with the dynamic perspective. It is also possible to compare these clusters on different measures, such as the level of creativity (novelty and usefulness).

Next, we tested the propositions of the two perspectives in two steps. In a first step, we tested a basic model in which duration of the different activities was used to predict creative outcomes. This analysis provides insight into which activities are more important to achieve creative outcomes. Because the different operationalizations of temporality (duration, frequency, timing, sequence) will be correlated (e.g., a higher frequency and earlier onset of engaging in an activity is likely correlated with the overall duration of engagement in that activity), in subsequent analyses we control for duration and test whether frequency, timing, and sequence have effects over and beyond those of duration.

Descriptive statistics

Table 2 shows the descriptive statistics. The means show that there were large differences among creative activities in terms of average duration. For example, on average individuals spent 298 seconds on problem construction ($SD = 213$ seconds), while spending 1,007 seconds on information search and encoding ($SD = 581$ seconds). Note that the long time spent on information search and encoding may well be a consequence of the sheer amount of information available (32 folders in total). Furthermore, the mean frequencies of engagement show that it was common for individuals to revisit all distinct activities multiple times over the course of the creative process. For example, individuals on average engaged in idea generation 9.29 times, and in problem construction 13.99 times. These average frequencies suggest that the creative process was to some extent dynamic in nature.

Correlations between duration measures and creativity show that novelty was positively related to duration of engagement in solution ($r = .22$, $p = .002$). Usefulness was marginally positively related to duration of engagement in information search (r

Table 2. Descriptive statistics.

	M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Novelty	2.52	1.02	-													
2. Usefulness	2.79	.74	.11	-												
3. (d)Problem construction	298.14	213.53	−.04	−.05	-											
4. (d)Information search	1006.84	581.73	−.04	.14°	.18*	-										
5. (d)Idea generation	336.40	255.28	.09	−.18**	.43**	.03	-									
6. (d)Solution	609.33	334.51	.22**	.16*	.16*	.12	.13°	-								
7. (f)Problem construction	13.99	8.66	.03	−.05	.54**	.30**	.27**	.31**	-							
8. (f)Information search	14.22	8.53	.05	.04	.44**	.43**	.27**	.33**	.88**	-						
9. (f)Idea generation	9.29	5.86	.04	−.01	.31**	.18*	.43**	.33**	.69**	.65**	-					
10. (f) Idea selection & elab.	5.15	3.76	.02	.07	.20**	.13°	.24**	.42**	.55**	.46**	.71**	-				
11. (t) Idea generation	616.65	592.14	.01	−.07	.27**	.27**	.14*	.00	.12°	.03	−.08	−.04	-			
12. (t) Idea selection & elab.	1400.74	848.21	.08	.02	.49**	.59**	.40**	.14*	.30**	.34**	.18*	.04	.59**	-		
13. (s) Non-adjacent switches	.26	.14	−.04	−.09	−.06	−.30**	−.03	.14*	.05	−.20**	.17*	.32**	−.13°	−.24**	-	
14. Total time	2309.78	871.80	.07	.09	.55**	.77**	.47**	.54**	.54**	.61**	.45**	.38**	.29**	.69**	−.16*	-
15. Total switches	47.27	25.15	.05	.00	.46**	.30**	.34**	.38**	.93**	.91**	.84**	.71**	.03	.28**	.05	.57**

N = 197, (d) = duration; (f) = frequency; (t) = timing onset; ^{0} $p < .10$; * $p < .05$; ** $p < .01$.

= .14, $p = .054$) and significantly to duration of engagement in solution ($r = .16$, $p = .025$). Usefulness was negatively related to duration of engagement in idea generation ($r = -.18$, $p = .010$). No significant correlations were found between novelty and usefulness on the one hand, and frequency, timing, and sequencing measures of the creative process on the other.

Additionally, the intercorrelations between different temporal measures provide some initial insight about the nature of the creative process. Firstly, although all frequency intercorrelations were high, the correlation between problem construction frequency and information search and encoding frequency was especially high ($r = .88$, $p < .001$), which may suggest that these two activities are very closely coupled. This may also explain why participants frequently engaged in both information search and encoding and problem construction (about 14 times each, on average): it seems that they used information to increase their understanding of the problem. Secondly, the timing of the onset of idea generation was positively correlated with the duration of "earlier stages" problem construction ($r = .27$, $p < .001$), and information search and encoding ($r = .27$, $p < .001$), hereby suggesting some degree of linearity in the creative process. That is, individuals who spent more time on problem construction and information search and encoding started later with idea generation. A similar pattern is visible for the timing of the onset of idea selection and elaboration, which correlated positively with the durations of problem construction ($r = .49$, $p < .001$), information search and encoding ($r = .60$, $p < .001$), and idea generation ($r = .40$, $p < .001$). However, given that these correlations do not approximate 1, we can conclude that the creative process was also relatively dynamic.

Sequence analysis

Sequence analysis is a family of methods developed to analyze ordered lists of items or states (Abbott, 1995). Originating from biology and developed to analyze strings of DNA, it has been adopted by the social sciences to discover meaningful patterns in states, transitions, and events across time. The main advantage of sequence analysis over related methods, such as event history analysis, is that it allows events and transitions in their continuum rather that focus on single events only (Aisenbrey & Fasang, 2010). As such, it is highly suitable and relevant for the present study, even more so since this analytical method can provide a descriptive view of different patterns in which creative activities can occur, while including indicators of duration, timing, frequency, and sequencing (Studer & Ritschard, 2016).

Figure 1 shows the sequence index plot for all participants in the study. In this plot, each horizontal line represents one individual sequence of activities with its absolute length (ordered according to absolute length). Based on the overall distribution of sequences, it appears that the creative process across individuals showed some linearity, with engagement of problem construction and information search and encoding being more prevalent in the beginning of the process, and engagement in idea generation, and idea selection and elaboration at the end. At the same time, however,

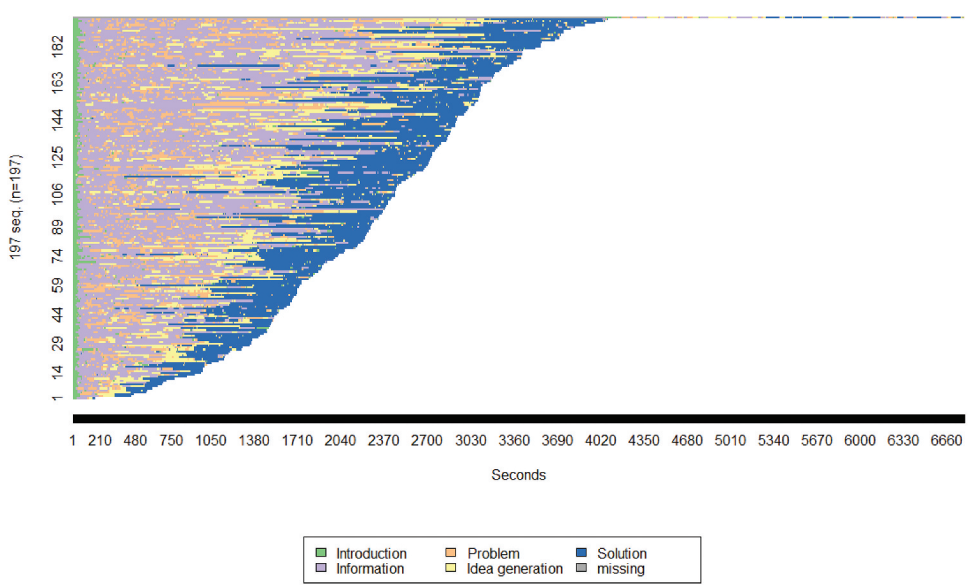

Figure 1. Sequence index plot, absolute length.

Table 3. Transition rates between stages of the creative process.

	Problem construction	Information search	Idea generation	Idea selection and elab.
Problem construction →	-	.20	.12	.02
Information search →	.25	-	.07	.02
Idea generation →	.06	.08	-	.10
Idea selection and elab →	.02	.02	.04	-

Rows represent the current process-stage, columns represent the target process to which the switch is made.

the figure also shows some iterative aspects, with individuals switching back and forth between activities over time.

Next, we examined transition rates to examine whether it is possible to identify certain frequent or typical transitions between specific creative activities. Table 3 shows the likelihood of switching from a specific activity (represented by the rows) to another activity (represented by the columns; note that all numbers together add up to 1). This table is informative in two ways. Firstly, the proportions give an indication which activity most likely followed a prior activity. Results show that problem construction was most likely followed by information search and encoding. Information search and encoding, in turn, was most likely followed by problem construction. Idea generation was most likely followed by idea selection and evaluation, and idea selection and evaluation was most likely followed by idea generation. Thus, in terms of the sequencing, there was a coupling between early-stage activities (problem construction, and information search and encoding) and late-stage activities (idea generation, and idea selection and elaboration).

Secondly, this table shows the most frequently observed switches, which informs us about the inner workings of the creative process. The most common switch was from information search and encoding to problem construction, suggesting that individuals mostly used information to build a thorough problem representation. The next most common switch was from problem construction back to information search and encoding, which might suggest that constructing the problem often cued individuals that they needed more information. Another very common switch was from problem construction to idea generation, suggesting that building a construction of the problem often elicited ideas that might help to solve the problem.

We next tried to identify meaningful patterns in this sequence data in order to find and group the sequences that are most similar and separate them from sequences that are most dissimilar (i.e., find clusters of participants who showed a similar sequence). To do so, we standardized the sequences to have the same length (1,000 time-units), and we used optimal matching (OM) analysis to calculate the relative distances between each individual sequence (Gabadinho, Ritschard, Studer, & Müller, 2009; Studer & Ritschard, 2016). To calculate the distances between individual sequences, OM works with substitution costs. It assigns a certain cost to substituting a state in a specific position in a sequence with the state that occurs in the other sequence in that same position. These substitution costs can be determined by the transition rates between each state, where states between which transitions occur more frequently are attributed lower substitution costs (see also Table 3).

Following the calculation of the distance matrix, we applied Ward's method for cluster analysis to group the most similar sequences and separate them from the least similar ones. To identify the optimal cluster solution, we inspected dendrograms and various measures for cluster quality (Studer, 2013). We selected a solution with two meaningful clusters, although various cluster quality measures indicated that the structure of the clusters should be considered weak or artificial (weighted Average Silhouette Width (ASWw) = .21, Point Biserial Correlation (PBC) = .43). However, this solution showed best fits on ASWw, and the PBC indicated that the solution was close to the optimal cluster distribution. Furthermore, trying different distance measures and clusters did not substantially improve quality statistics, and the two-cluster solution appears theoretically meaningful. Poor values on these measures are largely due to the length of the sequences: to find similarities in patterns with sequences of 1,000 items and frequent transitions is particularly challenging. However, the length of a 1,000 time-units was determined while any lower number would have meant the loss of switching information, and as such, would have painted a biased picture of how creative processes unfold over time.

Figure 2 shows state distribution plots for the two clusters that were selected. In the figure, the horizontal axis represents time (standardized across participants) and on the vertical axis it is shown how much time in a specific time unit was spent on all different activities. It is apparent from Figure 2 that cluster 1 (comprised of 148 individuals) represents a more iterative approach, whereas cluster 2 (49 individuals) represents a more linear approach. This can be seen mainly because the

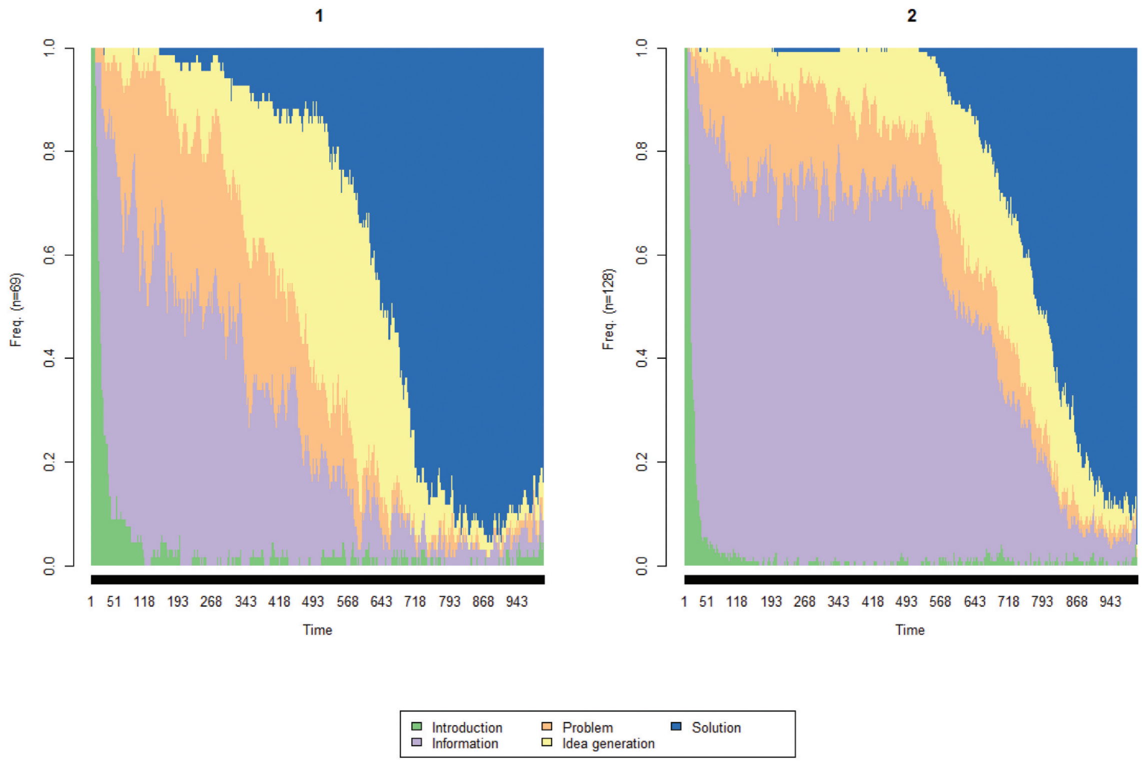

Figure 2. State distribution plots.

Table 4. Means, SD's, and t-tests for the two clusters.

	Cluster 1		Cluster 2		t-test	
	M	*SD*	*M*	*SD*	*t*	*p*
Novelty	2.61	1.00	2.22	1.07	2.34*	.020
Usefulness	2.79	0.76	2.78	0.68	0.12	.903
(d) Problem construction	302.76	227.29	283.18	166.43	0.53	.599
(d) Information search and encoding	808.20	466.91	1606.84	474.42	−10.34*	<.001
(d) Idea generation	354.07	271.21	283.03	192.25	1.70	.090
(d) Idea selection and elaboration	675.24	347.09	410.25	184.76	5.10*	<.001
(f) Problem construction	13.64	8.76	15.08	8.34	−1.01	.312
(f) Information search and encoding	13.43	8.44	16.61	8.48	−2.29*	.023
(f) Idea generation	9.47	6.01	8.76	5.38	0.74	.458
(f) Idea selection and elaboration	5.40	3.88	4.41	3.32	1.61	.110
(t) Idea generation	566.91	573.99	766.93	625.63	−2.07*	.040
(t) Idea selection and elaboration	1280.35	793.86	1764.39	910.02	−3.56*	<.001
(s) Proportion non-adjacent switches	0.28	0.14	.20	.13	3.43*	.001
Total Time	2199.97	883.12	2641.49	751.99	−2.14*	.002
Total Switches	46.73	25.72	48.92	23.52	−0.53	.599

(d) = duration; (f) = frequency; (t) = timing onset (s) = sequence of non-adjacent switches.

two clusters differ in the onset and relative attention to the late-stage activity of idea selection and development.

We next compared the two clusters on the different creative activity and outcome measures, using t-tests (see Table 4). Confirming the notion that Cluster 1 has more iterative characteristics than Cluster 2, we found that individuals in Cluster 1 spent significantly less time on information search and encoding (t =-10.37, $p < .001$), marginally more time on idea generation (t =1.70, $p = .090$), and significantly more time on idea selection and evaluation ($t = 5.10$, $p < .001$). Additionally, Cluster 1 reports earlier onset of both idea generation ($t = -2.07$, $p = .040$), and idea selection and evaluation ($t = -3.56$, $p < .001$). Furthermore, Cluster 1 was characterized by a higher proportion of non-adjacent switches (t =3.43, $p = .001$). For frequency, however, results are less clear: participants in Cluster 1 had lower frequencies of information search and encoding ($t = -2.29$, $p = .023$) and we found no differences for frequencies of other activities. However, apart from the results for frequencies, participants in Cluster 1 behaved more in line with the iterative perspective as compared

Table 5. Regression analyses of main effects and curvilinear effects of time spent (duration) in processes on novelty and usefulness.

	Novelty								Usefulness							
	Model 1				Model 2				Model 3				Model 4			
	B	*SE*	*t*	*p*	*B*	*SE*	*t*	*p*	*B*	*SE*	*t*	*p*	*B*	*SE*	*t*	*P*
Intercept	2.52	.07	35.42	<.001	2.52	.12	19.94	<.001	2.78	.05	54.15	.000	2.87	.09	32.10	<.001
(d)Problem construction	−.12	.08	−1.415	.159	−.12	.12	−1.02	.308	−.01	.06	−.12	.907	−.15	.09	−1.75	.083
(d)Information search	−.06	.08	−.77	.445	−.11	.09	−1.20	.231	.10	.06	1.78	.076	.16	.06	2.51	.013
(d)Idea generation	.13	.09	1.41	.161	.27	.12	2.24	.026	−.17	.06	−2.68	.008	−.15	.08	−1.73	.086
(d)Idea selection& elab	.23	.07	3.21	.002	.24	.09	2.73	.007	.13	.05	2.44	.016	.16	.06	2.56	.011
(d)Problem construction^2					.00	.05	−.05	.958					.07	.04	1.94	.054
(d)Information search^2					−.10	.08	1.17	.244					−.11	−.06	−1.87	.064
(d)Idea generation^2					−.08	.05	−1.65	.100					−.02	.03	−.49	.624
(d)Idea selection& elab^2					−.02	.06	.79	.794					−.06	.04	−1.34	.181

(d) = duration.

to those in Cluster 2, with: [a] a stronger emphasis on late-stage activities; [b] an earlier onset of late-stage activities; and [c] a stronger degree of unpredictability in the sequence of activities as indicated by non-adjacent switches.

We next compared the two clusters in terms of creative outcomes. Importantly, participants in Cluster 1 received a significantly higher score of novelty of their final solution ($t = 2.34$, $p = .020$) than those in Cluster 2. There were no differences in usefulness. This results tentatively suggests more support for the iterative perspective in the sense that participants whose behavior was more in line with that perspective were more creative. In what follows, we further examine our specific temporal propositions and shed more light on the nature of this finding.

Test of propositions

Duration

As a first step, we examined the relative importance of engagement in creative process activities by regressing novelty and usefulness on the duration of engagement in all activities. Specifically, *Proposition 1a* (linear perspective) suggests that engagement in problem construction and information search and encoding are most important in obtaining creative outcomes, while *Proposition 2a* (iterative perspective) suggests that engagement in selection and elaboration is the most important for the generation of creative outcomes. Before analysis, all independent variables were standardized.

Table 5 (Model 1) shows that novelty is positively related to time spent on idea selection and elaboration ($B = 0.23$, $t = 3.21$, $p = .002$), but not to any of the other activities. Furthermore, Table 5 (Model 3) shows that usefulness is also positively related to idea selection and elaboration ($B = 0.13$, $t = 2.43$ $p = .016$). In addition, results show a negative significant effect of idea generation on the usefulness of the solution ($B = -0.17$, $t = -2.68$, $p = .008$). Furthermore, we found a marginally significant positive effect of information search and encoding on the usefulness of the solution ($B = 0.10$, $t = 1.78$, $p = .076$).

Taken together, results suggest that idea selection and elaboration activities are important for both novelty and usefulness dimensions of the creative solution, thereby lending more support to *Proposition 1b*. Somewhat surprising, we found no positive effect of idea generation on novelty, and even a negative effect of idea generation on usefulness.

It is possible that the effects of duration are more complicated and that there is an optimum of engagement for each of these activities. After including curvilinear effects and regressing these on novelty (Table 5, Model 2), most effects remain the same. However, the main effect of idea generation on novelty becomes significant ($B = 0.27$ $t = 2.24$, $p = .026$), with a marginally negative significant curvilinear effect ($B = -0.08$, $t = -1.65$, $p = .100$), which suggests that spending more time on idea generation positively affects creativity only up to a certain amount (See Figure 3a). All other curvilinear effects on novelty were insignificant. With regard to the

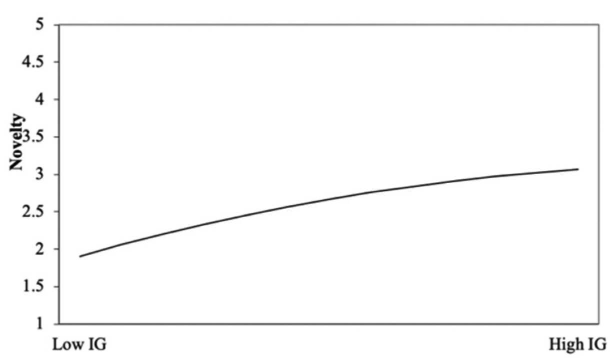

Figure 3a. Curvilinear effect of idea generation duration on novelty.

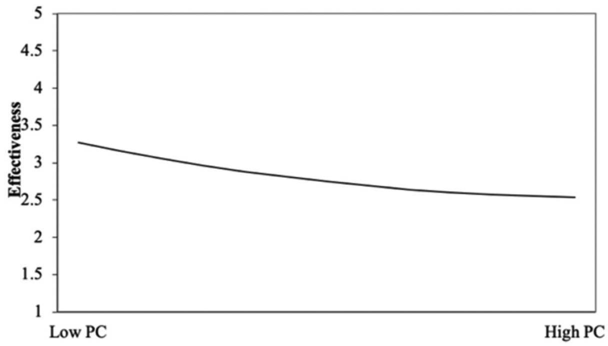

Figure 3b. Curvilinear effect of problem construction duration on usefulness.

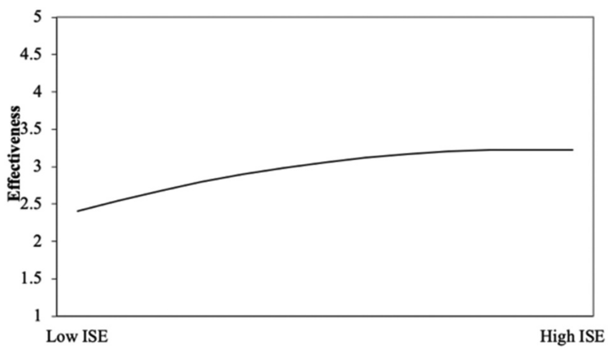

Figure 3c. Curvilinear effects of information search and encoding duration on usefulness.

effects of idea generation, it appears that engaging in idea generation more did lead to more original solutions, but that this effect leveled off. Moreover, this effect occurred at the expense of lower usefulness, suggesting that a trade-off between originality and usefulness.

With regard to usefulness (Table 5, Model 4), the main effect of problem construction on usefulness turned from being insignificant into being marginally negatively significant ($B = -0.15$, $t = -1.75$, $p = .083$), with a marginally positive significant curvilinear effect ($B = 0.07$, $t = 1.94$, $p = .054$), suggesting that spending more time on problem construction initially impacts usefulness negatively, after which spending more time on problem construction does not further impact usefulness (See Figure 3(b)). In addition, the prior marginally significant positive effect on information search and encoding on usefulness became fully significant ($B = 0.16$, $t = 2.51$, $p = .013$), with a marginally significant negative curvilinear effect ($B = -0.11$, $t = -1.87$, $p = .064$), suggesting that information search and encoding also positively relates to the usefulness of a solution only up to some extent, as is depicted in Figure 3(c).

Timing

As a second step, we examined *Proposition 1b*: The onset of idea generation, and idea selection and elaboration are positively related to creativity; and *Proposition 2b*: The onset of idea generation, and of idea selection and elaboration is negatively related to creative outcomes. We examined whether onset and offset contributed to the prediction of novelty and usefulness above and beyond the duration in creative activities. As depicted in Table 6, none of the onsets variables was significantly related to either novelty or usefulness of the final solution. Thus, in this specific context, *when* individuals engage in specific activities for the first time does not seem to have affected creative outcomes beyond the effects of duration. For example, this suggests that spending more time on idea selection and elaboration had positive effects, but it mattered less when this activity was started (earlier or later).

Frequency

We next examined whether the frequency of engagement in specific stages in the creative process was related to creative outcomes. Specifically, derived from the linear perspective, *Proposition 1c* suggests that frequency of engagement in creative process activities is negatively related to creative outcomes. In contrast, from the iterative perspective, we derived *Proposition 2c*, which suggests that frequency of engagement in creative process activities is positively related to

Table 6. Regression of onset of engagement in specific stages of the creative process on novelty and usefulness.

	Novelty				Usefulness			
	B	*SE*	*t*	*p*	*B*	*SE*	*t*	*P*
Intercept	2.51	.07	35.31	<.001	2.78	.05	54.09	<.001
(d)Problem construction	−.16	.09	−1.78	.077	−.02	.07	−0.35	.724
(d)Information search and encoding	−.16	.11	−1.47	.144	.06	.08	0.72	.472
(d)Idea generation	.06	.10	0.65	. 515	−.19	.07	−2.73	.007
(d)Idea selection and elaboration	.22	.07	2.91	.004	.13	.05	2.52	.012
(t)Problem construction	−.05	.14	−0.37	.712	.02	.10	0.19	.850
(t)Information search and encoding	.11	.11	0.99	.325	−.10	.08	−1.27	.207
(t)Idea generation	−.08	.11	−0.70	.483	−.06	.08	−0.73	.467
(t)Idea selection and elaboration	.23	.14	1.64	.103	.10	.10	.94	.350

[a](d) = duration; (t) = timing onset.

Table 7. Regression analyses of main effects and curvilinear effects of engagement frequency in processes on novelty and usefulness.

	Novelty								Usefulness							
	Model 1				Model 2				Model 3				Model 4			
	B	*SE*	*t*	*p*	*B*	*SE*	*t*	*p*	*B*	*SE*	*t*	*p*	*B*	*SE*	*t*	*P*
Intercept	2.51	.07	34.95	<.001	2.45	.10	25.27	<.001	2.78	.05	54.72	<.001	2.75	.07	40.42	<.001
(d)Problem construction	−.15	.10	−1.59	.114	−.16	.10	−1.61	.109	.08	.07	1.14	.256	.08	.07	1.12	.263
(d)Information search	−.08	.09	−.86	.390	−.08	.09	−.87	.387	.08	.06	1.26	.210	.07	.06	1.07	.286
(d)Idea generation	.16	.10	1.62	.107	.16	.10	1.58	.115	−.21	.07	−2.97	.003	−.21	.07	−3.08	.002
(d)Idea selection/elaboration	.26	.08	3.27	.001	.28	.08	3.35	.001	.10	.06	1.79	.075	.11	.06	1.97	.050
(f)Problem construction	.08	.18	.46	.648	.01	.20	.07	.947	−.35	.13	−2.74	.007	−.46	.14	−3.36	.001
(f)Information search	.04	.17	.22	.826	.10	.19	.56	.579	.22	.12	1.89	.061	.34	.13	2.62	.009
(f)Idea generation	−.06	.14	−.44	.664	−.04	.17	−.22	.824	.03	.10	.26	.792	.03	.12	.27	.790
(f)Idea selection/elaboration	−.12	.12	.99	.322	−.20	.15	−1.34	.182	.11	.09	1.31	.192	.07	.11	.63	.529
(f)Problem construction^2					.08	.09	.88	.378					.13	.06	2.04	.043
(f)Information search^2					−.08	.08	−.92	.358					−.13	.06	−2.36	.019
(f)Idea generation ^2					.00	.08	−.04	.967					.02	.06	.31	.751
(f)Idea selection and elab^2					−.06	.07	.78	.440					.03	.05	.48	.629

[a](d) = duration; (f) = frequency.
[b]Follow-up analyses were ran for main effects and curvilinear effects of frequency because of multicollinearity between problem construction and information search and encoding. These results are reported in the text.

Table 8. Regression of non-adjacent switches between specific stages of the creative process on novelty and usefulness.

	Novelty				Usefulness			
	B	*SE*	*t*	*p*	*B*	*SE*	*t*	*p*
Intercept	2.51	.07	34.99	<.001	2.78	.05	54.66	<.001
(d)Problem construction	−.17	.10	−1.70	.091	.07	.07	1.06	.292
(d)Information search and encoding	−.09	.09	−1.05	.296	.07	.06	0.11	.268
(d)Idea generation	.16	.10	1.57	.118	−.21	.07	−3.00	.003
(d)Idea selection and elaboration	.28	.08	3.41	.001	.11	.06	1.88	.062
(f)Problem construction	.17	.19	0.86	.289	−.31	.14	−2.26	.025
(f)Information search and encoding	−.08	.19	−0.40	.693	.17	.14	1.26	.210
(f)Idea generation	−.04	.14	−0.27	.785	.04	.10	0.36	.718
(f)Idea selection and elaboration	−.09	.12	−0.75	.452	.13	.09	1.43	.156
(s) Prop. Non-adjacent switches[a]	−.11	.10	−1.17	.245	−.05	.07	−0.74	.459

[a](d) = duration; (f) = frequency; (t) = timing onset (s) = sequence of non-adjacent switches.
[a]We also ran the analysis with a more stringent conceptualization of non-adjacent switches, including only PC-IS, ISE-IS, IS-PC, and IS- ISE. Results remained the same.

creative outcomes (P2c1), or follows an inverse U-shape (P2c2). Given the strong correlations between frequency and duration measures, we controlled for duration to examine the unique effect of frequency over and above duration.

As is depicted in Table 7 (Model 1), frequency of none of the creative activities was related to novelty. However, as shown in Table 7 (Model 3) we did find that individuals who engaged in problem construction more often (B = −0.35, $t = 2.74$, $p = .007$), developed solutions that were less useful. This result might imply that individuals who revisit problem construction often fail to converge on a full understanding of the problem, and consequently, are unable to devise a useful solution. In contrast, we found a marginally significant positive effect of information search and encoding frequency on usefulness (B = 0.22, t = 1.89, $p = .061$). Given the high intercorrelation between problem construction and information search and encoding frequencies, these results might be caused by multicollinearity. We therefore reran the analysis for problem construction without information search and encoding, and the effect remained significant ($B = -0.17$, $t = -2.00$, $p = .047$). We also reran the analysis for information search and encoding without problem construction, and found the result disappeared ($B = -0.02$, $t = -.27$, p =.792), thereby suggesting that multicollinearity indeed impacted these results. Taken together, the results of frequency of engagement in creative activities on creative outcomes seem to neither support the linear perspective, nor the iterative perspective convincingly, given that few significant effects were found.

In addition, we examined curvilinear effects for frequency. Results are depicted in Table 7 (Models 2 and 4). For novelty, all main effects stay the same, and no curvilinear effects were found. For usefulness, the main effects also stay largely the same. However, we found a positive curvilinear effect for problem construction (B = 0.13, t = 2.04, p =.043), and we found a negative curvilinear effect for information search and encoding (B = −0.14, t = 2.74, p =.019). These effects, however, were caused by multi-collinearity: both effects disappeared when not controlling for the other. Taken together, we found no evidence of curvilinear effects of frequency on creative outcomes.

Sequencing

Finally, we looked at the specific order in which individuals engage in specific activities. Specifically, derived from the linear perspective, *Proposition 1d* proposed that the proportion of non-adjacent switches between creative activities is negatively related to creativity, whereas *Proposition 2d* suggests that the proportion of non-adjacent switches between creative activities is positively related to creativity. For this analysis, we control for both duration and frequency. We added the frequency measures as control variables because we wanted to examine whether non-adjacent switches were especially contributive or detrimental to creativity, regardless of the total switching frequencies. As Table 8 shows, the proportion of nonadjacent switches is not related to novelty (B = −0.11, t = −1.17, p =.245), and not related to usefulness (B = −0.05, t = −.74, p =.459).

Exploratory analysis

The high correlations between frequency variables (Table 2), and the transition rates between specific processes (Table 3) indicate that some processes are closely coupled (e.g., problem construction and information search and encoding). This raises the question whether such coupling influences creative performance. We therefore computed for each pair of processes (six in total) the proportion of switches between these two processes. We found that usefulness was positively related to the extent to which information search was coupled with idea generation (r = .15, p = .043), and to the extent to which information search was coupled with idea selection and elaboration (r = .18, p = .012). Conversely, usefulness was negatively correlated which the coupling between problem construction and idea generation (r = −.18, p = .011). However, in a regression in which we controlled for all duration effects, none of the coupling effects remained significant.

Discussion

In recent years, various scholars have advocated the importance of incorporating temporality in studying the creative process (Lubart, 2001; Runco, 2019; Steele, 2019). However, theoretical frameworks on the creative process have only implicitly addressed how creative processes should unfold over time to be successful, and prior research has not translated these implicit expectations into explicit temporal propositions. In this paper, we identified two different perspectives on the creative process, namely a linear and an iterative perspective. Using the taxonomy of Aguinis and Bakker (2021), we proposed that the linear perspective is characterized by a relative emphasis on problem construction and information search and encoding, a lower frequency of switches between activities, a later onset of idea generation and idea selection and evaluation, and a sequence consisting of a lower proportion of non-adjacent switches. Conversely, we proposed that the iterative perspective is characterized by a stronger relative emphasis on idea selection and elaboration, a higher frequency of switches between activities, an earlier onset of idea generation and idea selection and elaboration, and a higher proportion of non-adjacent switches. Developing these propositions is important, because it enabled us and future research to more precisely examine specific temporal properties of the creative process and their relations with creative outcomes.

Moreover, we developed a task paradigm that can capture temporal aspects of the creative process as it unfolds. Specifically, we devised a task in which we split up the creative process in problem construction, information search and encoding, idea generation, and idea selection and evaluation. Individuals could navigate freely among these activities, and the framework measured in real-time which activity the participant performed. This experimental framework can be used to capture creative process engagement unobtrusively (Reiter-Palmon & Robinson, 2009) by using a micro-longitudinal framework (Beghetto & Karwowski, 2019). This framework might therefore be useful for others to test temporal propositions regarding the creative process.

Finally, we used the task to explore whether we could give some initial insights into how the creative process unfolds over time and what consequences this has for creative outcomes. First, sequence analysis indicated that different people approached the same task in different ways. One, relatively large cluster of people followed a more iterative approach, in which they showed a stronger engagement in late-stage activities, an earlier onset of late-stage activities, and a higher degree of nonadjacent or chaotic switches. Another, smaller cluster of people seemed to follow a more linear approach and had a stronger focus on the preparatory activity of information search and encoding (both in duration and frequency), a later onset of late-stage activities, and a lower proportion of non-adjacent switches. Interestingly, those who followed the iterative approach were on average more creative than those who followed the linear approach and had higher scores on novelty (but not usefulness).

Second, we found mixed results across our temporal propositions. Although we did not find any significant effects for our *timing* (i.e., timing of the onset of an activity) and *sequence* variables (i.e., adjacent versus non-adjacent switches between activities), we did see effects for duration and frequency. With regard to *duration*, the results support the iterative perspective more strongly than the linear perspective. The proposition based on a strict linear perspective, suggesting that problem construction and information search and encoding serve as the foundation for generating creative ideas, was not supported: the duration of engagement in these activities was not related to the novelty of the final solution. Some curvilinear effects on usefulness were found for these activities, with a decreasing negative effect of problem construction on usefulness, and a decreasing positive effect of information search and encoding, but these are not consistently in line with either perspective. In contrast, we found more support for propositions informed by the iterative perspective, which highlights the importance of idea selection and elaboration. We found that idea selection and elaboration, operationalized as time spent on the solution page, was positively related to both novelty and usefulness of the final solution, confirming that after initial idea generation, additional novelty and usefulness can be achieved in idea selection and elaboration. In addition, we found a positive main effect and a marginally significant curvilinear effect of idea generation on novelty, and a negative main effect of idea generation on usefulness, suggesting that extensive idea generation had both upsides and downsides. This last result is consistent with findings that suggest that originality may sometimes go at the expense of usefulness (e.g., Nijstad, De Dreu, Rietzschel, & Baas, 2010).

For *frequency*, results were mixed. More specifically, the linear proposition that increased frequency of engagement in specific activities is negatively related to creativity was only supported for the relation between problem construction and usefulness. The fact that problem construction frequency is negatively related to usefulness of the solution is interesting, because it could suggest that fragmented problem construction might occur when individuals are not able to converge on an integrative problem representation, which in turn makes it harder to develop a solution to effectively solve the problem. No further effects of frequency were significant, and taken together, the results for frequency do not clearly support one perspective over the other. This implies that the question whether the creative process is more effective when it is relatively ordered or chaotic (Lubart, 2001) is, for now, left unanswered.

In sum, results tentatively support the iterative perspective more than the linear perspective: participants who followed a more iterative process produced solutions that were more original than those who followed a linear perspective, and the duration of engagement in idea selection and elaboration was positively related to both originality and usefulness of the final solution.

Limitations and future research

This study has several limitations that need to be considered. A first potential limitation revolves around the information that was shared with the participants during the task. That is, although the problem presented to the participants was based on an actual problem that the educational sector in the Netherlands faces, and therefore was quite realistic, the participants were only provided with a relatively small selection of all information that is available for this problem. The real-world version of this problem is therefore much more complex, and the process of coming up with a novel and useful solution for the problem would likely unfold over a much larger timespan, ranging from several weeks to multiple months. Thus, studying the creative problem-solving process on this problem in real-life, in a sample of professionals might yield different results. However, the provision of limited information is not uncommon in research on the effects of information search and encoding (Harms, Reiter-Palmon, & Derrick, 2020; Illies & Reiter-Palmon, 2004).

Additionally, the design of the framework we used may have some limitations. Firstly, we did not randomize the order of the buttons in the navigation panel in our experimental framework. As a result, we may have nudged individuals to engage in activities in a specific order, thereby influencing the linearity of the processes. In addition, although we aimed to not manipulate engagement in specific stages of the creative process, by offering participants the option to freely navigate between problem construction, information search and encoding, idea generation, and idea selection, we did elicit their awareness of these differential behavioral options and, as such, might have implicitly manipulated active engagement (Reiter-Palmon & Robinson, 2009). Thirdly, although we believe that our instructions to navigate to a specific process page whenever one was engaged in said process was successful[3] we cannot fully exclude the possibility that individuals were cognitively engaged in a different process than implied by the page they were on in that moment, which might have created additional noise in the data.

A third potential limitation might be that the empirical part of this paper is of an exploratory nature. That is, instead of testing hypotheses, we tested competing propositions, and conducted follow-up analyses. This increases the likelihood of type I errors, and our results should therefore be interpreted as initial findings that require follow-up research. Furthermore, we must consider that our results are at least to some extent task-specific. For example, Mumford, Antes, Caughron, Connelly, and Beeler (2010) showed that different creative process activities contribute differently to creative achievements in distinct scientific disciplines. In addition, Lubart and Guignard (2004) concluded that creativity is not a generalized ability regardless of the task domain, which may also suggest that the creative process differs across task domains and disciplines (see also Lubart, 2001; Reiter-Palmon, Illies, Kobe Cross, Buboltz, & Nimps, 2009, 2009).

Indeed, one of the most important issues in this regard is generalizability of the current results. We certainly do not claim that all our results will generalize, and we believe that many findings may be specific to our task and population. For example, findings may be different depending on task complexity, level of interest or involvement in the problem, prevailing norms or customs (e.g., organizational culture), or expertise of those that perform the task. Future research should therefore look into the conditions under which the adoption of a specific strategy leads to either success or failure. That is: when does a more linear or iterative approach in fact lead to creative outcomes, and when does it fail in doing so? For example, more complex or less well-defined tasks may require more iteration in the creative process than less complex or more clearly defined tasks. Developing and testing ideas along these lines would greatly enhance our understanding of the dynamics of the creative process.

Future research can also investigate how dispositional and contextual variables influence the temporal aspects of specific creative process strategies that individuals apply. For example, prior research shows that individuals differ in their cognitive styles (Kozhevnikov, 2007), the extent to which they prefer multitasking (McKay & Gutworth, 2021), and in their willingness to actively process information (Kruglanski, 1990). These variables may shape several temporal aspects of the creative process. For example, individuals who prefer multitasking might be more creative when they approach the creative process in an iterative manner involving high frequencies of switching and more nonadjacent switches. In contrast, individuals who prefer structure might benefit more from a linear approach to creativity, characterized by low switching frequencies and a lower proportion of nonadjacent switches. Alternatively, individuals who are high in need to avoid closure spend more time on understanding a problem, whereas those who are high in need for closure jump more readily to solutions. Finally, the extent to which individuals' decision-making in the creative process is a rational vs an intuitive process is an interesting avenue for future work. Specifically, following the conceptualization of intuition as shaped by prior experience (e.g., Dane & Pratt, 2007), it could be explored how prior experience with creative processes shapes creative process approaches that individuals follow (i.e., more iterative or more sequential).

Contributions

This paper contributes to the creativity literature and the creative process literature in several ways. Firstly, we derived explicit temporal propositions from existing theoretical perspectives of the creative process, and as such, we believe we provide the field with more explicit and precise temporal constructs that can be studied in relation with the creative process. In doing so, we have answered the call of several scholars (Lubart, 2001; McKay & Gutworth, 2021; Runco, 2019; Steele, 2019), who have advocated that the creativity field should more explicitly examine the role of time and temporality in the creative process.

Secondly, we developed an experimental method that enables researchers to examine engagement in different creative activities over the course of a problem-solving task, in a relatively unobtrusive manner. Although this method needs further validation, for example by examining whether similar results are derived for non-student samples, and whether results are comparable for different problem-solving tasks, we believe our paradigm might be an important first step toward a better methodology to capture the creative process as it unfolds over time.

Finally, we were able to shed some light on the question to what extent the temporal propositions from the linear perspective and the iterative perspective are valid, and which temporal aspects of the creative process actually impact creative performance. Taken together, we believe that much more research is necessary to develop a better understanding of the role of temporality in the creative process. At the same time, we hope that this work inspires researchers to dive deeper into the temporal questions that still need to be answered.

Notes

1. Although we make a distinction between more linear and more iterative perspectives, we do not imply that particular researchers can be classified in one or the

other "camp" about this issue, or that there is a strong theoretical disagreement among different "camps". Mostly, scholars differ in the extent to which they view the creative process as more linear or more iterative. As such, views range from more linear to more iterative.

2. Nonlinear Dynamic Systems Theory or Chaos theory is another stream, that will be disregarded here because it does not allow for making very specific predictions (Schuldberg, 1999).
3. In a follow-up analysis, we found strong correlations between the frequency of problem construction, and the number of described problem elements ($r = .57$, $p < .001$), and between idea generation and idea generation fluency ($r = .41$, $p < .001$), thereby suggesting that participants followed the suggestion to move to these respective pages whenever they thought of something related to the problem, or whenever an idea that would help in a potential solution would come to mind.

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Data availability statement

The authors hereby claim that the data as well as the syntax supporting our results can be archived in a public repository.

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