Planning in Action: Interactivity Improves Planning Performance

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Abstract

Planning is an everyday activity that is extended in time and space, yet is frequently studied in the absence of interactivity. Successful planning relies on an array of executive functions including self-control. We investigated the effects of interactivity and self-control on planning using a sequential-task paradigm. Half of the participants first completed a video-viewing task requiring self-control of visual attention, whereas the other half completed the same task without the self-control constraint. Next, and within each of these groups, half of the participants manipulated cards to complete their plan (high-interactivity condition); for the other half, plans were made with their hands down (low-interactivity condition). Planning performance was significantly better in the high- than in the low-interactivity conditions; however the self-control manipulation had no impact on planning performance. An exploration of individual differences revealed that long-term planning ability and non-planning impulsiveness moderated the impact of interactivity on planning. These findings suggest that interactivity augments working memory resources and planning performance, underscoring the importance of an interactive perspective on planning research.

Keywords: personal planning, time management, distributed cognition, self-control, ego depletion

Introduction

Planning is an essential cognitive process that is key to achieving productive time management. Successful planning depends on the ability to anticipate a sequence of operations intended to achieve one or more goals, requiring the capacity to effectively delay and resume the pursuit of goals, according to current resources and constraints (Hayes-Roth & Hayes-Roth, 1979; Patalano & Seifert, 1997). The planning process may involve *initial planning;* a systematic, rational approach where solutions are formulated ahead of plan execution (Morris & Ward, 2004). As such they are subject to constraints on processing, including working memory resources. An alternative to this top-down model is *opportunistic planning* where the plan develops in situ driven by incoming information, rather than being entirely goal-directed in advance of any moves (Davies, 2005). Selection of initial or opportunistic planning is based on the problem complexity and environment, and individual differences (Davies, 2005).

Efficient planning depends on the coordination of a variety of executive functions, ranging from formulating a sequence of sub-goals that together embody a plan, storing and updating the plan, consciously monitoring, up to controlling and coordinating the plan to effect the desired outcome (Morris & Ward, 2004). This view suggests that successful planning depends on two key cognitive concepts: working memory and self-control. Self-control is defined as "the exertion of control over the self by the self" (Muraven & Baumeister, 2000, p. 247), occurring when a person attempts to override or inhibit the way they would otherwise think or behave. Working memory is a memory system for temporal information, and is a key theoretical concept for understanding how a limited amount of information is kept temporarily highly available, integrating external and previously-stored information in order to facilitate cognition and complex behaviour (Logie & Cowan, 2015). Working memory capacity has been linked with the ability to control attention (Engle & Kane, 2004) and avoid impulsive interferences. These are important requisites of self-control (Broadway, Redick, & Engle, 2010). With multiple perspectives and potential actions held in working memory during planning, self-control seems key to planning appropriate actions and suppress inappropriate ones. This conception of planning, however, assumes that people solely rely on their mental resources when they engage in planning tasks. Yet real-life planning admittedly involves more than just mental processing: people who plan do so by making notes, writing and rearranging "to-dos" in lists, emails or index cards. In other words, they not only access but also interact with external information by manipulating to-dos while they plan.

Distributed Cognition and Interactivity

Traditionally, thinking is considered to occur in the head, sandwiched between perceptual inputs and behavioural outputs (to adapt Hurley, 2001). More recently an epistemological shift to a distributed cognition perspective proposes a dynamic cognitive system whose structure is distributed across the internal resources of the individual (such as acquired knowledge) and the resources external to the individual (such as material representations and tools; e.g., Kirsh, 2010). Studies of planning are conventionally conducted in the absence of a distributed cognitive system and with a focus on the "temporal ordering of action" (Kirsh, 1995, p. 31). Interactivity, by contrast, configures a dynamic agent-environment system scaffolded from resources internal and external to the agent. In all likelihood, interacting with the physical feature of a problem results in a simpler problem configuration that engages perceptual and pattern matching processes. In addition, by changing the spatial rearrangement, non-strategic manipulations may serendipitously determine what to do next. In mental arithmetic, for example, moving number tokens when performing long sums enhances accuracy and improves efficiency (Vallée-Tourangeau, 2013); congenial, easy-to-remember interim totals can be identified and physically segregated, action affordances shift as the problem configuration is transformed, the allocation of attentional resources is governed by dynamic changes in the problem. Similarly, in a Bayesian reasoning task, manipulating cards representing elements of a statistical sample led to a sharp increase in performance (Vallée-Tourangeau, Abadie, & Vallée-Tourangeau 2015). One possible explanation for the positive impact of interactivity on performance is that increasing interactivity reduces the processing burden on an agent's working memory. If this is the case, we should expect that higher levels of interactivity and resulting opportunities to manipulate and rearrange information in a planning task should promote better planning performance.

Self-control

Self-control is required to maintain goal intentions and plans over time, and resist the conflicts of immediate impulses such as attending to tempting stimuli. (Hofmann, Friese, & Strack, 2009). Research into failures of self-control (acting on impulses) proposes that it is a finite mental resource that limits self-regulatory capability. Motivated by this approach Baumeister and colleagues (e.g., Baumeister, Bratslavsky, Muraven, & Tice, 1998) developed the strength model of self-control with the central tenet that willpower is a limited resource akin to energy, which becomes fatigued or depleted with use, temporarily reducing the capacity for subsequent self-control. Baumeister et al. (1998) termed this state of reduced self-control *ego depletion*. Support for the model comes from research using a sequential-task paradigm; participants are required to engage in an initial task of self-control, and decrements in their performance are then measured on a second, unrelated task of self-control. A meta-analysis of 83 sequential-task studies reported a medium effect size (Cohen's d = .62) of ego-depletion (Hagger, Wood, Stiff, & Chatzisarantis, 2010).

More recently, the ego-depletion effect has been called into question with studies failing to detect the phenomenon (e.g., Lurquin et al., 2016). A reanalysis of the Hagger et al. (2010) data and another meta-analysis identified small-study bias and an inflated effect size (Carter & McCullough, 2014). This was followed by a multi-lab Registered Replication Report (RRR) involving 23 labs worldwide which found an overall ego-depletion effect of close to zero (Hagger et al., 2016). This RRR used just one combination of tasks, and the present study responds to the recent calls for further replications using different combinations of tasks, increased sample sizes, and to investigate potential moderating variables (e.g., Lurquin et al., 2016).

Since planning involves self-control activities such as monitoring and coordinating actions, we should expect ego depletion to impair planning performance. Yet, as interactivity may offer a platform for offloading some of the cognitive processing required to monitor and coordinate action, we anticipate that the impact of ego depletion on planning performance will be tempered when cognitive agents are free to physically interact with their plan.

The Present Experiment

Despite its ubiquity and importance in everyday life, planning research to date has tended to focus on planning dysfunctions and the order of actions, ignoring both the environment in which planning takes place and the cognitive state with which the participant comes to the task. This research typically uses one of two general types of tasks: *puzzle-based tasks*, which involve simple, mechanistic, easily-controlled procedures (e.g., the Tower of London), or *real-world planning tasks*, which invoke familiar procedures and contexts of a complexity analogous to everyday activities (Morris & Ward, 2004; e.g., the Virtual Planning Task, Miotto & Morris, 1998). The present experiment adopted a distributed-cognition perspective to determine how the manipulation of task interactivity and ego-depletion would affect performance on a real-world planning problem. We designed a low-interactivity condition using a static paper presentation during which participants had to keep their hands down, while in the high-interactivity conditions cards corresponding with to-be-executed tasks could be manipulated and re-arranged as participants saw fit. Both conditions required working memory and self-control to switch and control attention between remembering plans and actioning them. We hypothesised that the inflexible, unmodifiable environment offered in the low-interactivity condition would lead to poorer performance relative to the high-interactivity condition. Since planning is reflected in physical changes in the environment, we hypothesised that the high-interactivity condition would lead to improved performance relative to the low-interactivity condition.

A secondary aim of this experiment was to test whether the offloading of cognitive processing afforded by highly interactive environments could act as a buffer for the negative impact of depleted self-control resources on planning performance. We selected a widely-used ego-depletion task (e.g., Schmeichel, 2007), along with a planning task that is demanding of executive control in order to maximise the chances of demonstrating the ego-depletion effect. The experimental set-up replicated as closely as possible that of the original author (Brendan Schmeichel), including a verbatim script of the original task that was obtained with the help of the authors of the recent replication study (Lurquin et al., 2016). We nearly doubled the sample size used in typical ego-depletion studies. Participants were allocated to either a control or an experimental ego-depletion group, the latter requiring self-control in order to direct attention towards an interviewee and away from distracting words presented on the screen. In order to understand what participants in both conditions were really doing during the video-viewing task, and to ensure the two conditions were indeed distinct, supplementary measures such as a word memory task to test adherence to instructions and additional questions regarding the ego depletion task were included. Based on the resource model of self-control participants in the ego-depletion condition, who performed the initial act of self-control, should perform worse in the subsequent planning task than participants in the control condition. Though, given the conflicting findings in the extant literature, and our new combination of tasks, we set out with an exploratory perspective on the effect of this frequently-used video-viewing task combined with our planning task.

In addition, we included self-report measures of flow, planning, and impulsivity to explore whether they would moderate the impact of interactivity on planning performance.

Method

Participants

One hundred participants (73 women, 27 men, M_{age} = 31.90 years, *SD* = 11.77) were recruited; some received course credits. All participants were naive to the purpose of the research.

Procedure

The experiment employed a 2 (interactivity: high or low) x 2 (ego depletion: depletion or control) between-groups design. Participants were randomly allocated to one of the four experimental conditions (*n* = 25 per group). All tasks were completed in a single testing session, lasting approximately 45 min, which was divided into three phases. Participants first watched the ego-depletion video. This was followed immediately by the planning task. Finally, participants completed a series of self-report measures.

Ego-depletion task. Participants watched a 6 min, silent video featuring a woman being interviewed by an off-screen interviewer, as the initial task in a sequential-task paradigm (Schmeichel et al., 2003). During the video 36 common, one-syllable words (e.g., "play"*)* appeared at the bottom of screen for 10 s each. Words appeared in black font on a white background and took up approximately one quarter of the screen.

In the ego-depletion condition participants were instructed to focus attention on the woman's face and not to look at the words that appeared on the screen. The control condition was identical except, crucially, no instructions were given regarding the words that appeared on the screen and participants were asked to watch the video as if they were "sitting at home watching TV". While participants viewed the video, the experimenter moved outside the room. Two modifications were made to the original task. First, distance between participant and screen was standardised at 40cm. Second, to increase their saliency, the position of the words was changed from bottom right to bottom centre. The size, colour and font remained unchanged.

Planning task. Next, participants completed an adapted version of Miotto and Morris's (1998) planning task in either the low-interactivity list condition, or the high-interactivity board game condition. The object of the task was to plan and execute a sequence of specified activities on the four days of the week preceding a trip abroad. Twenty-eight activities were offered for completion, 16 of which were relevant to the trip. The remaining 12 activities were not relevant and were termed "distractors". To simulate the constraints of real world planning, once the participant had executed the activities for a given day they could not change their plan and had to move on to the next day. Participants were seated at a desk and instructed on the main features and rules of the task. They were advised that they could carry out four tasks per day; two in the morning and two in the afternoon and that not all tasks could be completed. There was no time limit but participants were instructed to complete the task as quickly and as accurately as possible. Two measures were used to calculate planning performance: (1) accuracy – a choice of task was considered correct if it was one of the 16 relevant activities, and where applicable, completed on the specified day and time; (2) latency per correct task – calculated as overall latency divided by accuracy.

Figure 1: The experimental setting, high-interactivity condition (left), and low-interactivity condition (right).

High-interactivity condition. The 28 activities were printed on individual action cards (55 x 88mm). These action cards could be selected by moving the card into a central day frame split into sections representing the morning and afternoon. As in the low-interactivity condition, a summary card which specified which activities needed to be done during the week was always available. Finally, an execution board was used to place cards that had been selected and representing tasks that have been completed (see Fig. 1, left panel). Participants were handed the 28 activity cards in a randomly ordered pack and were free to move the cards as desired in the working area. Participants could monitor their goal progress at any stage by checking the execution board.

Low-interactivity condition. The low-interactivity condition used a list of 28 activities to be performed (see Fig. 1, right panel). In this condition participants were instructed not to touch any task materials and to keep their hands on the desk for the duration of the task. To choose a task for completion participants verbally instructed the experimenter of their selection.

Additional Measures. Upon completion of the planning task, participants answered a flow questionnaire developed to gauge participant's enjoyment and engagement during a task (Vallée-Tourangeau et al., 2015). Next, all participants were given a surprise memory test for the words presented during the video in the first part of the experiment. The test compromised 36 words: 18 that appeared during the initial video-viewing task, and 18 that did not (the same test designed by J. H. Lurquin, personal communication, 2 March 2016). Participants then judged whether they had seen the words previously by circling either *yes* or *no*. The memory test was followed by a series of manipulation checks for the ego depletion task. Participants were asked to rate the difficulty of complying with the video task instructions they were given prior to watching the video (1 = *not at all difficult* to 10 = *very difficult*). Following Lurquin et al. (2016) participants also rated how much effort they had put in to the task, and how hard they had tried to ignore or remember the words (1 = *none* to 10 = *a lot*).

Finally, participants completed individual differences measures of planning and impulsivity as an independent measure of planning ability. Participants completed Simons and Galotti's (1992) planning survey, a 31-item scale measuring everyday planning style, and Lynch, Netemeyer, Spiller and Zammit's (2009) propensity to plan for time short run and long run 6-item scales. This is a 30-item scale, scored using three sub-scales: attentional, motor and non-planning.

Results

Depletion participants rated the video task as more effortful (M = 7.38, SD = 1.99) than did the control participants (M = 6.74, SD = 2.32), however the difference was not significant, $t(98) = -1.48$, $p = .142$. Participants in the depletion condition remembered significantly fewer words (M= 4.66, SD = 4.31) than control participants (M = 12.78 = SD = 3.72), $t(98) = 10.09$, $p < .001$, which suggests that they complied, in part, with the task instructions. Although, if the depletion participants had fully complied with the instructions then they would not have remembered any words.

The main dependent measure in the planning task was accuracy, the maximum possible score being 16; the data are reported in Figure 2. Participants in the high-interactivity condition were more accurate than those in the low-interactivity condition, but the ego-depletion paradigm appeared to have no effect on planning performance. A 2 x 2 between subjects analysis of variance (ANOVA) revealed a significant main effect of interactivity, $F(1, 96) = 78.03$, $p < .001$, but neither the main effect of ego depletion nor the interaction effect were significant (Fs < 1).

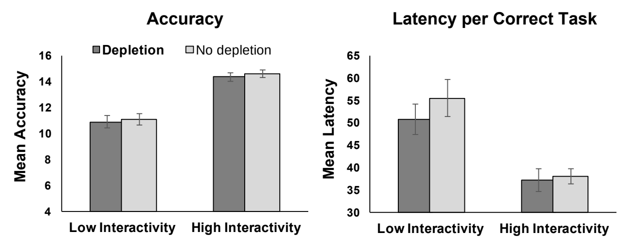

Figure 2: Mean accuracy (left panel) and mean latency per correct task (in seconds, right panel) as a function of level interactivity and the experience of the ego depletion task (error bars are standard error of the means).

Latency per correct task was calculated as total latency divided by accuracy; lower scores reflect better performance. Figure 2 shows that generally participants in the high-interactivity condition were faster than those in the low interactivity condition. A 2 x 2 independent ANOVA revealed a significant main effect for interactivity $F(1,96) = 25.72$, $p < .001$. Again, neither the main effect of ego depletion nor the interaction effect were significant (Fs < 1).

We explored whether individual differences in planning, impulsiveness, and experience of flow moderated the impact of interactivity on planning performance. Planning performance was positively associated with flow, $\beta = .22$, $t(96) = 2.45$, $p = .016$, although flow was not a moderator of the interactivity effect on planning performance; $\beta = .03$, $t(96) = 0.36$, $p = .72$. More interestingly, the impact of interactivity on planning performance was moderated by individuals' propensity to plan in the long-run, $\beta = -.15$, $t(96) = -2.08$, $p = .04$. Specifically, higher propensity to plan in the long-run was associated with higher performance under low interactivity but it did not predict performance under high interactivity (see Figure 3, left panel). The impact of interactivity on performance was also moderated by non-planning impulsiveness, $\beta = .16$, $t(96) = 2.22$, $p = .03$. In this case, higher scores of non-planning impulsiveness were associated with higher planning performance under high levels of interactivity and lower planning performance under low levels of interactivity (see Figure 3, right panel).

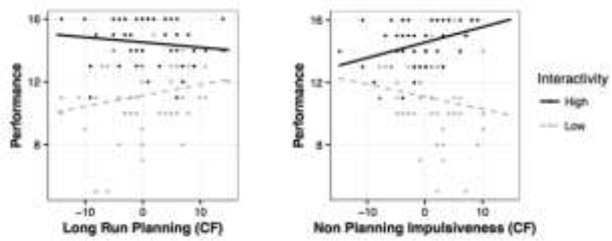

Figure 3: Relationship between planning accuracy (Performance) and propensity to plan in the long run (left panel) and non-planning impulsiveness (right panel) as a function of interactivity levels (High vs. Low). *Note*. CF = Centred Form or mean deviation form.

Discussion

In this experiment participants completed a planning task in two different interactivity conditions, one which permitted spatial rearrangement of the task, and one which did not. Generally, participants were more accurate and achieved faster latency per correct answer in the high-interactivity condition. These results can be explained in terms of the affordances provided by the different task environments. In the low-interactivity condition participants were forced to manipulate information mentally, relying on executive function-directed initial planning. As such, performance was limited by the participants' working memory capacity.

In contrast, the dynamic interface of the high-interactivity condition facilitated new affordances for task completion and paved the way for opportunistic planning, where task selection was guided, in part, by the physical changes in the configuration of the problem. Planning was interspersed with physical execution, alleviating the load on the participants' working memory compared to the complex initial planning in the head required by the low-interactivity constraints. The significant increase in task performance in this condition could not be attributed to individual differences since there were no condition differences on measures of planning. Instead, the high-interactivity environment allowed participants to re-structure and simplify the problem presentation in a way that was conducive to solving the task. For example, reorganising the activity cards made it possible to collate related activities, discard distractor cards and constantly track the state of the task. Furthermore, when participants planned all time-specific tasks first, they then perceived the gaps left in the plan, thus placements for single item tasks were physically discovered (Kirsh, 2010).

We sought to explore cognitive individual differences that would predict performance in both conditions of the planning task. We hypothesised that the skills implicated when planning in the head would be different from the skills employed when planning in a distributed environment. Long Run Planning ability only mattered for those participants in the low interactivity condition; it had no effect on performance in the high interactivity condition. Conversely, high levels of non-planning impulsivity put people at an advantage under high interactivity, and at a clear disadvantage in the low interactivity condition. The fact that planning performance was superior in the high-interactivity, in the absence of a difference in self-reports of planning ability, suggests that the manipulation of cards augmented planning abilities (via working memory) above those measured with planning scales. This finding supports previous work (e.g., Vallée-Tourangeau, Sirota, & Vallée-Tourangeau, 2016) and suggests that interactivity may functionally augment cognitive resources.

Self-Control and the Elusive Ego Depletion Effect

The present experiment also examined the effect of ego depletion on planning. As advocated by Lurquin et al. (2016) we used a larger than average sample size (N = 100) and explored a new combination of tasks. Despite making these and other modifications to this highly-replicated depletion task, the main effect of ego depletion was not significant. This result is inconsistent with the strength model (Baumeister et al., 1998), and many previous studies, including those from the laboratory where the term ego depletion was first coined, and where the video-viewing task was developed. However, it is consistent with more recent research that has failed to detect the ego-depletion effect, and most notably Lurquin et al. (2016), which used the same initial video-viewing task.

A critical pre-requisite of the sequential-task paradigm is that both tasks require the use of self-control. The present planning task has not been used as a second task in the sequential task paradigm: one possible explanation for the absence of ego depletion is that the outcome planning task did not require self-control. Yet, there is little doubt that planning requires the deliberate control of actions across time, and Baumeister and Vohs (2016) argue that planning draws on the same limited resource as self-control. Additionally, in the present study, task constraints such as adhering to activities stipulated on the summary card required that impulses to follow habitual holiday-planning responses be overridden using self-control. Further, it could be argued that the low-interactivity instructions demand self-control by requiring participants to keep their hands down on the table. Despite apparently meeting the conditions necessary to induce the ego-depletion, we found no evidence of an effect. Since the video-viewing task lacks an objective measure of task performance (Lurquin & Miyake, 2017), we included the word memory task and assume that performance here points to adherence to the video task instructions. Participants in the ego-depletion condition remembered some words, indicating that they looked at them and so did not fully adhere to the task instructions. If participants in this condition did not inhibit their natural impulse to respond to the attention-capturing words, they were not using self-control in the first task and thus would not be, and indeed were not, depleted in the second task. Without substantial modification to the task procedure and an objective measure of performance, our findings indicate that the video-viewing task does not operationalise ego-depletion as intended.

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