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Touchy Thinking: Interactivity Improves Planning Performance

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Author Note

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Abstract

Planning is an everyday activity that is extended in space, often recruiting external resources to enhance performance. Yet planning activity is frequently studied in the absence of interactivity in laboratory conditions. Success in goal-orientated planning relies on an array of executive functions including self-control which is a limited resource. Exerting self-control may temporarily reduce the capacity for subsequent self-control, therefore impairing executive function. This phenomenon is called ego depletion. The experiment reported here investigated the effects of task interactivity and ego depletion on planning using a sequential-task paradigm. Using a between-groups design, participants completed an everyday planning task in two interactivity contexts. In the low-interactivity condition plans were made with hands down. In the second, high-interactivity condition participants were free to modify cards to complete their plan. Before that, half of the participants undertook a video-viewing ego-depletion task during which the focus of visual attention was controlled. Performance was measured in terms of accuracy, total latency, and latency per correct task. The main effect of ego depletion was never significant. However, as expected planning performance was significantly better in the high- than in the low-interactivity conditions. Participants also felt significantly more engaged with the task when they could manipulate the cards. These findings suggest that interactivity augments working memory resources and ameliorates planning performance, thus underscoring the importance of an interactive perspective on planning research.

Touchy Thinking: Interactivity Improves Planning Performance

Planning is an essential cognitive process that pervades everyday human activity. Even the most ordinary day inevitably comes with a plan: what time to leave for work, what to eat for lunch, how to spend the evening (Hayes-Roth & Hayes-Roth, 1979). The likelihood of successful goal attainment is substantially improved by planning the “what, where and when” of that goal (Maglio, Gollwitzer, & Oettingen, 2014). Despite its ubiquity and importance in everyday life, research to date has explored planning in terms of its underlying processes and dysfunctions, leaving it relatively underexplored from a cognitive psychology perspective. Here planning is considered from a different viewpoint; that of the factors that may determine successful real-life planning in healthy adults.

The remainder of the introduction is structured as follows: First, an overview of current planning models and paradigms is presented. This is followed by a summary of the executive functions associated with planning. Next the strength model of self-control and the current issues surrounding ego depletion are discussed. The concept of interactivity is introduced and a distributed cognition perspective on planning is explored. The rationale for the current experiment, as well as its design, close the Introduction.

Planning

Models and theories of planning. Successful planning is defined as 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 plan itself is the representation of this sequence, held internally (in the head) and/or externally (e.g., a map, a to-do list). Plans have three general characteristics: (1) an *initial state*, from where the

planner starts; (2) a *goal state*, the state the planner aims to achieve; (3) the steps taken by the planner to transform the initial state into the goal state (Sternberg & Ben-Zeev, 2001).

The process of planning is essential to almost all decision making and problem solving (Simons & Galotti, 1992). In much of the theoretical literature on planning, the terms “problem solving” and “planning” are used interchangeably (e.g., Unterrainer & Owen, 2006). Here pertinent problem-solving models are utilised. One of the earliest and most influential accounts of planning was Miller, Galanter, & Pribram's (1960) human information-processing theory. Miller et al. argued that a plan is the intention to achieve a desired goal through action, and that the action is repeated and tested until the goal is achieved (Morris & Ward, 2004). This concept provided the basis of many subsequent theories of problem solving, including that of Simon (1978) and colleagues (Newell & Simon, 1972). This account characterises planning as an interaction between individuals and the environment, resulting in the individual generating a mental representation of the problem called the *internal problem space* (Morris & Ward, 2004). Within this problem space all possible states of the problem are integrated allowing the individual to select moves by considering appropriate actions and their consequences (Unterrainer & Owen, 2006). Such models of planning suggest a systematic, rational approach where solutions are formulated ahead of plan execution. As such they are subject to constraints on processing resources (e.g., working memory), meaning it is not possible to search for all possible permutations in order to solve a problem. Individuals instead tend to rely on *heuristics* – rules of thumb that are most likely to produce a solution. We shall refer to such planning as *initial planning*.

An alternative to this top-down model is *opportunistic planning*; participants react to opportunities and conflicts as they emerge, rather than adhering to a predetermined solution (Hayes-Roth & Hayes-Roth, 1979; Patalano & Seifert, 1997). In a classic study by Hayes-Roth and Hayes-Roth (1979) participants completing an errands task used multiple strategies

and shifted those strategies opportunistically. For example, they may have initially been using the strategy “complete the more important goal first” but then pass the location of a less important goal and switch to a “complete goals by proximity” strategy (Patalano & Seifert, 1997). In other words, current observations revealed unplanned opportunities and the plan was amended accordingly. Such models suggest that the plan develops in situ driven by incoming information, rather than being entirely goal-directed in advance of any moves (Davies, 2005). Davies suggests that the factors that may affect the selection of initial or opportunistic planning include the complexity of the problem, the problem environment, and individual differences.

Planning literature. The extant planning literature primarily focuses on the prefrontal cortex as an important structure in executive function with damage to this area producing poor planning and decision making (Miyake et al., 2000). Planning tasks such as those described below, have been used to reveal deficits in executive function related to frontal lobe lesions (Goel, Grafman, Tajik, Gana, & Danto, 1997; Goel et al., 2013; Miotto & Morris, 1998; Owen, 1997; Shallice, 1982), and frontal lobe dementia (Carlin et al., 2000). Research also reports the neural correlates of planning (Baker et al., 1996; P. W. Burgess, Veitch, de, & Shallice, 2000; Schall et al., 2003; Unterrainer & Owen, 2006), and the development of planning of abilities in children (Davidson, Amso, Anderson, & Diamond, 2006; Kaller, Rahm, Spreer, Mader, & Unterrainer, 2008; McCormack & Atance, 2011).

Planning tasks. Laboratory studies of planning behaviour typically use one of two general approaches (Morris & Ward, 2004). The first being a puzzle-based task involving simple, mechanistic, easily-controlled procedures, for example the Tower of London task (TOL; Shallice, 1982). This well-established transformation problem-solving task is widely used to assess planning ability as a prototypical executive function in both healthy and clinical populations (Debelak, Egle, Köstering, & Kaller, 2015). The task requires

manipulation of three balls of differing colours to conform to visual-spatial solutions in the minimum number of moves (Luciana, Collins, Olson, & Schissel, 2009). Participants are provided with an initial state, the required goal state, and told how many moves they have to complete the task. Planning is evidently necessary in this task, both to plot the optimal problem-solving path and to avoid early incorrect moves that will render the problem unsolvable (Unterrainer & Owen, 2006). However, such tasks have been criticised for presenting highly-constrained planning situations that are unfamiliar and do not reflect real-life (Burgess, Simons, Coates, & Channon, 2005).

In recognition of the fact that everyday planning is different from laboratory-based paradigms, the second approach uses real-world planning situations involving familiar procedures and contexts of a complexity analogous to everyday activities (Morris & Ward, 2004). In this category is the VIRTUAL Planning Task (*sic*) originally developed by Miotto and Morris (1998) for frontal lobe patients, and adapted for use in the present study. This task involves the planning and execution of four days' worth of activities prior to a fictional trip abroad. Each day is organised by selecting activities from an array of *action cards* corresponding to a *summary card*, simulating a "to-do list". The cards include 16 target activities along with 12 distractor activities and participants must differentiate between these. Each day is planned by selecting the correct four action cards and placing them on a central *execution board*, the latter simulating their execution. In the original study the frontal lobe patients tended to select inappropriate activities (i.e., those not specified by the summary card), while control participants performed close to ceiling (Miotto & Morris, 1998). In order to assess efficient planning in healthy participants the original study has been modified, details of which are discussed below.

Executive Functions

Efficient planning depends on the coordination of a variety of executive functions. Executive functions describe a set of interrelated cognitive functions, reliant on the prefrontal cortex, that are called upon when behaviour cannot be automatic, but instead requires deliberate monitoring, control of thought and conflict resolution (Blair & Ursache, 2011; Kool & Botvinick, 2014). In this process of regulation and coordination, it is generally agreed that executive functions include *working memory* (described below); *inhibitory control*, defined as the inhibition of automatic non-optimal responses; and *cognitive flexibility*, defined as the ability to flexibly shift attention and adjust behaviour accordingly (Blair & Ursache, 2011). In order to complete many everyday activities it is necessary to formulate a sequence of sub-goals that together embody a plan, store and update the plan in working memory, consciously monitoring, controlling and coordinating the plan to effect the desired outcome (Morris & Ward, 2004).

Working memory. Everyday planning requires working memory and it is the cognitive process most often highlighted in planning tasks (Hayes-Roth & Hayes-Roth, 1979; Miller et al., 1960; Owen, Downes, Sahakian, Polkey, & Robbins, 1990). Working memory is the key theoretical explanation for how a limited amount of information is kept temporarily highly available, integrating external and previously stored information in order to facilitate cognition and activity (Logie & Cowan, 2015; Vandierendonck, 2016). One of the most influential frameworks of executive function is Baddeley and Hitch (1974) and Baddeley's (1986) multiple-component model of working memory. The model consists of three components. Two are specialised temporary memory systems: the phonological loop for processing and storing verbal information and the visuo-spatial sketchpad for visual and spatial information (Baddeley & Logie, 1999). In addition the model includes a supervisory

system called the central executive, responsible for executive functions and linked to the functioning of the frontal lobes (Miyake et al., 2000).

The extent to which working memory, and specifically which components, relate to planning efficiency has been a topic of considerable debate (Hambrick, Kane, & Engle, 2005). Spatial working memory was a strong predictor of success in Logie, Trawley, and Law's (2011) multiple-errands task; a task with complex rules and a map to navigate. Studies using the TOL task reveal similar findings implicating the visuo-spatial sketchpad and central executive (Gilhooly, Phillips, Wynn, Logie, & Della Sala, 1999; Gilhooly, Wynn, Phillips, Logie, & Sala, 2002; L. Phillips, Wynn, McPherson, & Gilhooly, 2001), however others argue that the task requires active verbal rehearsal (Morris, Ahmed, Syed, & Toone, 1993; Shallice, 1982). In contrast Ward and Allport (1997) found that working memory did not limit the performance on the TOL task. Although the precise relationship between planning and working memory remains undefined, we assume that as a general function, working memory will serve to hold and manipulate information in the participant's head in the present task.

Self-control. With multiple perspectives and potential actions held in working memory, self-control is required to plan appropriate actions and suppress inappropriate ones. In everyday life control of self is an important application and adaptation of executive function, specifically inhibitory control (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Inzlicht & Marcora, 2016). 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. The ability to exert will and abstain from immediate temptations (Metcalf & Mischel, 1999) enables people to engage in goal-directed behaviours and achieve long-term desirable outcomes (Dubner, 2016; Fishbach & Labroo, 2007) and is therefore essential for successful planning. This effortful

control is predictive of a wide variety of personal and social behaviours, including higher self-esteem (Tangney, Baumeister, & Boone, 2004), academic success (Duckworth & Carlson, 2013), general intelligence (Daly, Delaney, Egan, & Baumeister, 2015), crime, and premature death (Baumeister, Muraven, & Tice, 2000).

Ego Depletion and the Strength Model

Research into failures of self-control proposes that it is a finite mental resource that limits self-regulatory capability (e.g., Baumeister & Heatherton, 1996). Motivated by this approach and Freud's (1961) energy model¹, Baumeister and colleagues (Baumeister et al., 1998; Baumeister et al., 2000; Baumeister, Vohs, & Tice, 2007) developed the *strength model* of self-control. The central tenet of the model is that willpower is a limited resource akin to energy. Analogous to a muscle, willpower becomes fatigued or depleted with use, but may also be strengthened through conditioning (Baumeister et al., 2007). When the self, or executive function, expends willpower it temporarily reduces the capacity for subsequent self-control (Baumeister et al., 1998). Baumeister et al. (1998) termed this state of reduced self-control *ego depletion*.

Ego-depletion paradigms. Support for the model comes from research that uses two proximal, unrelated self-control tasks, known as *dual-task* (Baumeister et al., 1998) or *sequential-task* (Sripada, Kessler, & Jonides, 2014) paradigms. Participants are required to engage in an initial task of self-control. Decrements in their performance are then measured on a second, unrelated task of self-control. Adopting this paradigm, Baumeister et al. (1998) initially demonstrated the phenomenon with participants who were instructed to either eat chocolate cookies or to resist eating the tempting cookies and eat radishes instead. The use of self-control in this first task would have a detrimental effect on the second task - solving an impossible puzzle. The ego-depleted radish eaters showed reduced willpower and gave up on

the task twice as quickly as the cookie eating controls. Baumeister et al. (1998) argues that the fact that the two tasks required very different acts of self-control suggested that they both draw on one common limited resource, and that this constrains capacity for control and measured decision making. In this ego-depletion state automatic processes continue to operate un-depleted, and with weakened executive control, automatic processes may occur without restraint or inhibition, resulting in decisions being made using intuitive reasoning (R. Baumeister & Vohs, 2016). Since the initial demonstration of ego depletion, the effect has been demonstrated across domains such as logical reasoning (Schmeichel, Vohs, & Baumeister, 2003), decision making (Bruyneel, Dewitte, Vohs, & Warlop, 2006), working memory, and emotion inhibition (Schmeichel, 2007). An initial meta-analysis of 83 sequential-task studies, reported a medium effect size (Cohen's $d = .62$) of ego-depletion and suggested preliminary support for the strength model.

Outstanding questions and reliability of the ego-depletion phenomenon. While Hagger, Wood, Stiff, and Chatzisarantis (2010) provided initial support for the ego depletion effect, they also reported a range of factors that might moderate the effect size including depleting task duration, task complexity and inter-task interim period. Lurquin et al. (2016) suggested that task adherence in both the depletion and control condition, as well as individual differences in effort, may impact the depletion effect size. Furthermore, some studies have reported results evidently inconsistent with the limited resource account; if the depletion of a resource underlies self-control, then it should not be instantly restored by incentives (Muraven & Slessareva, 2003), or maintained by more autonomous motivation (Moller, Deci, & Ryan, 2006)

Despite numerous studies replicating the ego depletion effect, and the intuitive appeal of the strength model's muscle analogy, the precise mechanisms of depletion remain unclear (Inzlicht & Berkman, 2015). One influential theory suggested that glucose is necessary for

exertion of cognitive control and that the ego-depletion effect reflects a depletion of blood glucose levels (Baumeister et al., 2007). This assertion has been widely challenged and contradicted, primarily on the basis that cognitive effort consumes insubstantial amounts of glucose (Beedie & Lane, 2012; Boyle et al., 2016; Kurzban, 2010; Vadillo, Gold, & Osman, 2016). With the nature of the resource in doubt, the strength and robustness of the ego-depletion effect have been called into question by recent failed replications (e.g., Carter & McCullough, 2013; Lurquin et al., 2016; Xu et al., 2014). Some of the most pervading criticisms of the ego-depletion effect come from a reanalysis of Hagger et al.'s (2010) data and another meta-analysis which identified small-study bias (i.e., the proclivity for studies with small samples to produce larger effect sizes) and an inflated effect size (Carter & McCullough, 2014). This was followed by a multi-lab Registered Replication Report² involving 23 labs worldwide which found an overall ego-depletion effect of close to zero (Hagger et al., 2015).

It is in this context that the present study replicates one of the most widely-used video-viewing sequential-task paradigms in combination with a planning task. Baumeister and Vohs (2016) agree that planning may draw on the same limited resource as self-control, in that planning relies on the deliberate control of actions across time. Planning was linked to overcoming ego depletion in a study by Webb and Sheeran (2003). They showed that by having a good plan, and thus reducing the number of choices faced by participants, ego depletion could be counteracted. To our knowledge, a planning task has not been used as the outcome task in a dual-task ego-depletion paradigm. That is to say, the effect of ego depletion on planning - the reverse of the Webb and Sheeran (2003) experiment – has not been investigated.

Distributed Cognition and Interactivity

Traditionally, thinking is considered to occur in the head, sandwiched between perceptual inputs and behavioural outputs (Hurley, 2001). In this conventional explanation, understanding, as in “grasping” and “seeing” connections between facts are “psychological acts” (Grimm, 2010, p.342) that take place in the head. More recently an epistemological shift to a distributed cognition perspective radically challenges this idea. Instead this burgeoning movement suggests 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; Hollan, Hutchins, & Kirsh, 2000; Kirsh, 2010; Villejoubert & Vallee-Tourangeau, 2011). Many now argue that cognition extends beyond brains and bodies into the world (the *extended mind* thesis; e.g., Clark & Chalmers, 1998). The consequences of this thesis raise questions about thinking and knowledge, such as the relationship between knowledge and cognitive ability if that ability relies on the use of external resources (Pritchard, 2010; Toon, 2015) through interactivity.

Studies of planning are traditionally conducted in the absence of interactivity with a focus on the “temporal ordering of action” (Kirsh, 1995, p. 31). However, Kirsh (2010) argues that successful planning depends on a dynamic feedback loop in which information perceived from the environment is used to modify plans in the head, which in turn is used to alter the environment, and so on. This feedback loop was recognised in early accounts of planning and problem solving (e.g., Miller et al., 1960; Newell & Simon, 1972) yet it has seldom been the focus of research. Recently, however, this action-perception loop has been studied under the term *interactivity* (Villejoubert & Vallee-Tourangeau, 2011). Defined as a “sense-saturated coordination that contributes to human action” (Steffensen, 2013, p. 196) in which “a person alters the outside world, [and] the changed world alters the person” (Kirsh, 2010, p. 441). In the present study this approach was extended in order to investigate the way

in which the nature of available interactions in the task environment determines the ability to solve a planning task. This builds on previous work (e.g., Weller, Villejoubert, & Vallée-Tourangeau, 2011) which shows that individuals spontaneously manipulate and adapt their external environment in order to reduce cognitive load, make better use of their skills, and improve performance.

Interactivity literature. Classic examples from interactivity studies include expert “Tetris” players physically rotating pieces to facilitate perceptual processing (Kirsh & Maglio, 1994), and “Scrabble” players moving tiles to aid formation of words (Maglio, Matlock, Raphaely, Chernicky, & Kirsh, 1999). In these studies participants manipulate their environment and in so doing make their mental job easier, quicker and more accurate. Participants in high-interactivity conditions are likely to make more moves because the cost of these moves (e.g., rearranging Scrabble tiles) is small relative to imagining it in the head (e.g., Guthrie, Vallée-Tourangeau, Vallée-Tourangeau, & Howard, 2015). However, when the cost of external information increases, individuals may once again rely on internal information even if this is imperfect (e.g., Gray & Fu, 2004). Here thinking involves literal grasping and seeing to reveal solutions. Moves or actions include gestures, manipulation of artefacts, and even self-talk. These gestures and artefacts couple with internal resources forming an extended cognitive system, which feedbacks to advance understanding and enable solutions (Clark & Chalmers, 1998). In the present experiment, the additional resources provided by interacting with the cards were relatively cheap, as they were *epistemic* and *complementary actions* like moving and rotating objects as described above.

Functions of interactivity. The dynamic interplay between individuals and physical space has been associated with improved performance, indicated by speed and accuracy (Guthrie & Vallée-Tourangeau, 2015). Clearly, a key function of interactivity is to provide a memory aid so working memory can be offloaded to the environment (Zhang, 1997). The use

of more moves in the high interactivity conditions also suggests that interactivity lightens cognitive load by allowing an idea to be explored and tested quickly in the environment (Clark, Kirsh, Goldin-Meadow, & Rogers, 2011). Beyond this, it also serves to transform the original representation making it more cognitively congenial, revealing affordances and opportunities (Kirsh, 1996). By literally changing the spatial rearrangement, non-strategic manipulations may determine the next move(s). For example in Fioratou and Cowley's (2009) cheap necklace experiment, solutions in the interactive group were found via insight but also serendipitously when the necklace was manipulated in an unpremeditated way. Adopting a distributed-cognition perspective in the present study allows us to investigate the affordances of spatial manipulations. Kirsh (1995) suggests three key affordances: (1) simplifying choice; (2) simplifying perception; (3) simplifying internal computation.

Engagement and Flow

The term flow was coined by (Csikszentmihalyi, 1990; 1997) and is conceptualised as a state of deep absorption and engagement in an activity that is intrinsically enjoyable. Flow is believed to occur when one's skills are matched to the challenge of the task (Shernoff, Csikszentmihalyi, Shneider, & Shernoff, 2003) and when concentration, interest and enjoyment in that activity are experienced simultaneously (Csikszentmihalyi, 1997). Flow is likely to be moderated by level of interactivity. For example Shernoff et al. (2003) found that students were more engaged when they had more control over a task, and that positive experiences elicited by the task improved performance. Furthermore, Guthrie and Vallée-Tourangeau (2015) reported that participants had significantly more positive attitudes toward highly interactive conditions compared to static conditions.

The Present Study and Research Questions

Previous studies of planning tend 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. The present experiment was designed to exceed traditional investigations, adopting a distributed-cognition perspective to determine how the manipulation of task interactivity and previous ego-depletion would affect planning performance. More specifically, the present study had two main goals. The first major goal was to establish the effect of level of interactivity on planning by comparing performance on a static, errands planning task with performance on a high interactivity version where participants could physically manipulate their environment. The second goal was to investigate the effect of a previous ego-depleting task on planning performance. The present study took the form of a sequential paradigm in which participants first completed an ego-depletion task followed by the planning task.

Planning task. Planning tasks such as the TOL provide the opportunity to physically manipulate the problem configuration but may make unnatural cognitive demands. Furthermore, many real-life tasks make more realistic cognitive demands but limit or eliminate interactivity. As such, both methodologies produce a distorted view on real-life planning. The present paradigm was designed to give a more ecological perspective on planning by permitting the rearrangement of the elements configuring a real-life planning problem. Level of interactivity was manipulated while participants in both conditions were required to solve the same task. To facilitate two levels of interactivity, we designed a low-interactivity condition using static paper presentation during which participants had to keep their hands down. We hypothesised that this inflexible, unmodifiable environment would lead to poor performance relative to the high-interactivity condition. The high-interactivity condition, in which interactivity was unrestricted, provided a more naturalistic setting for

planning within the constraints of the laboratory. Participants freely interacted with playing cards and a board representing a calendar. Since here mental processes are supported by the environment, we hypothesised that this condition would lead to improved performance relative to the low-interactivity condition. Previous research suggests that participants in high-interactivity conditions have more control over their environment, coupled with reduced cognitive load. We therefore further predicted that participants in the high-interactivity condition would also report higher levels of flow.

Ego-depletion task. In response to a call from Lurquin et al. (2016) we replicated their study using the video-viewing task which has consistently been shown to induce ego depletion (e.g., Schmeichel, 2007; Stillman, Tice, Fincham, & Lambert, 2009). 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. We selected the most-widely used ego-depletion task, 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, including a verbatim script of the original task taken from personal communication with the author via Lurquin et al. (2016). The sample size of 50 participants per condition was selected since it is nearly two times the typical sample size used in ego-depletion studies ($n = 27$ per condition; Hagger et al., 2010).

In order to understand what participants in both conditions were actually doing during the video-viewing task, and to ensure the two conditions were indeed distinct, additional measures such as a word memory task to test adherence to instructions and additional questions regarding task effort were included. These are described in full below. Based on the resource model of self-control we hypothesised that participants in the ego-depletion condition, who performed the initial act of self-control, would perform worse in the

subsequent planning task than participants in the control condition. Furthermore, since the magnitude of the ego-depletion effect varies with cognitive demand, we predicted that the high-interactivity condition may provide a buffer to the effects of ego-depletion such that participants in the low-interactivity condition would show greater ego-depletion effects compared to participants in the high-interactivity condition.

Planning and impulsivity. In addition, measures of self-report planning and impulsivity were included to provide an independent assessment of planning ability. We hypothesised that certain participant characteristics may predict task performance: High levels of impulsivity would predict performance in the high-interactivity condition where dynamic, opportunistic planning was available and solutions could be revealed through action. Since success in the static condition would rely on systematic, initial planning, high levels of planning behaviour would predict performance in the low-interactivity condition.

Method

Participants

One hundred healthy adult volunteer participants (73 women, 27 men, $M_{\text{age}} = 31.90$ years, $SD = 11.77$) were recruited from Kingston University, London ($n = 74$) in exchange for course credits, and from Red Eyewear Ltd, London ($n = 26$). Participants signed up to a study on planning and were naive to the purpose of the research.

Participants completed a demographic questionnaire in order to screen for exclusion criteria (see Appendix A for full criteria). All participants had normal or corrected-to-normal vision and reported to be fluent in English. Since age-related effects have been frequently observed in planning tasks (e.g., TOL; Gilhooly et al., 1999), individuals 65 years and older were excluded from the study.

Design

The design was 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: (high interactivity ego depletion: $n = 25$; high interactivity control: $n = 25$; low interactivity ego depletion: $n = 25$; low interactivity control: $n = 25$).

Materials and Procedure

The experimental procedures were approved by the University of Kingston's Research Ethics Committee. Participants provided informed consent before participating and were advised that they could withdraw at any stage. All data were anonymised and confidential. There was no risk of harm to participants during the study, although participants were advised that the task required sustained attention which they may find demanding.

Contact between researcher and participants was minimised by using a script. The script also served to ensure that each participant received exactly the same instructions. All tasks were completed in a single testing session, lasting approximately 45 min, which was divided into three phases. In the first phase, participants watched the ego-depletion video. This was followed immediately by the planning task. Finally, all participants completed self-report measures in pencil-and-paper format before being thanked and debriefed.

Ego-depletion task. First, participants watched a 6 min, silent video featuring a woman being interviewed by an off-screen interviewer³, 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 (see Figure 1). Stimuli were generated on a 10 in. iPad.

In the ego-depletion condition participants were instructed to focus attention on the woman's face and not to read or look at the words that appeared on the screen. They were told that later they would be asked to answer questions about the woman's nonverbal behaviour. 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". For the full instructions for both conditions see Appendix B. While participants viewed the video, the experimenter moved outside the room.

Figure 1. Still from original video task (left panel), and from our modified version (right panel).

Modifications to original task. Two modifications were made to the original task. First, distance between participant and screen was standardised at 40cm. Second the position of the words was changed from bottom right to bottom centre. The size, colour and font remained unchanged⁴ (see Figure 1).

Planning task. Next, participants completed the planning task, representing the second part of sequential-task paradigm. The task presented a semantically identical planning task completed 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 (Monday to Thursday) preceding a trip abroad on Friday. The summary card stipulated the tasks to be completed before the trip (see Appendix C). All participants had access to the summary card throughout the task. To simulate the constraints of real world planning, once the participant had executed the activities for a given day they could not change their mind and had to move on to the next day. Participants were not advised of a time limit but were asked to complete the task as quickly and as accurately as possible.

Task activities. Twenty-eight activities were offered for completion, 16 activities of which were relevant to the trip. The remaining 12 activities were not relevant and were termed *distractors*. Tasks covered a range of complexities with activities falling in to the following overlapping categories: single item activities (4 Items); two-part activities (3 Items); three-part activities (2 Items); and time specific activities (7 Items). See Appendix D for complete details.

High-interactivity condition. The high-interactivity format and materials replicated those used by Miotto and Morris (1998) with minor modifications. The workspace and materials consisted of: (1) A desk serving as the working area; (2) 28 activities printed on individual *action cards* (55 x 88mm; see Figure 2). Action cards could be selected by moving the card into a central *day frame*; (3) the day frame was headed by a *day card* to specify which day of the week was being worked on and split into sections representing the morning and afternoon; (4) a *summary card* which specified which activities needed to be done during the week. An identical summary card was used in the low-interactivity condition; (5) an *execution board* was used to place cards that had been selected and representing tasks that have been completed. See Figure 3 for an image of high-interactivity experimental condition.

Figure 2. Sample of cards used in high-interactivity condition.

Participants were seated at a desk and instructed on the main features and rules of the task (see Appendix E for full details). 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. When instructed, participants read the summary card. Participants were then handed the 28 activity cards in a randomly ordered pack and were free to place and 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 simple paper list to communicate the 28 activities to be performed (see Figure 3). Two differently randomised versions⁵ of the activities list were alternated between participants. Participants were seated at a desk and instructed on the main features and rules of the task (see Appendix E for full details). This included the instruction 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. In this condition participants had no access to the execution board, and therefore no permanent representation of tasks that had been completed.

Figure 3. The experimental setting, high-interactivity condition (top), and low-interactivity condition (bottom).

Modifications to original task. The task was modified to challenge healthy adults and increase the requirement to plan ahead. The eight tasks to be completed were outlined on the summary card. In the original version of the study, tasks were explicitly described (e.g., *get a guide book*). In the modified version, tasks required interpretation before they could be carried out (e.g., “your trip is short and you want to make sure you know where all the top attractions are”). Two updates were made to the original task activities to ensure all were well known and easily understood within the study population: (1) “Buy some films for your

camera” was updated to “Buy a memory card for your camera”, (2) “Go to the bank and get some travellers cheques for your trip” was updated to “Go to the bank and get some Euros for your trip”.

Task completion and performance. In the high-interactivity condition task completion was defined as the selection of 16 tasks; four tasks per day, split between two in the morning and two in the afternoon. In the low-interactivity condition task completion was defined as selection of tasks for Thursday afternoon, the previous days’ activities already having been selected. Three measures were used to calculate planning performance: (1) accuracy - a task was considered to be correct if it was one of the 16 relevant activities, and where applicable, completed on the specified day and time; (2) total latency; (3) latency per correct task – calculated as latency divided by accuracy.

Flow scale. Following the planning task, participants completed a flow questionnaire developed to gauge participant’s enjoyment and engagement during a task (Vallée-Tourangeau, Abadie, & Vallée-Tourangeau, 2015; see Appendix F). Based on Shernoff et al. (2003), the questionnaire is a 9-item scale designed to measure the key dimensions of flow: engagement (concentration, interest and enjoyment), challenge, skill, and attention, and state of mind (anxiety and relaxation). Participants scored items on an 8-point scale (0 = *definitely not* to 7 = *definitely yes*). Negatively phrased statements were reverse coded. The scale was found to be highly reliable (Cronbach’s $\alpha = .74$).

Video word memory task. Next, participants were given a “surprise” memory test. The test comprised 36 words: 18 that appeared during the initial video-viewing task, and 18 that did not, J. H. Lurquin (personal communication, March 02, 2016). Participants were asked to judge whether they had seen the words previously by circling either *yes* or *no*. Instructions varied between ego-depletion conditions (see Appendix G for details).

Video scale. In accordance with the original task, all participants were asked to rate the difficulty of performing the instructions they were given prior to watching the video (1 = *not at all difficult* to 10 = *very difficult*). Following (Lurquin et al., 2016), participants additionally 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*; see appendix H).

Planning survey. Planning was assessed using the planning survey (Simons & Galotti, 1992); a 31-item scale measuring everyday planning style (see Appendix I). Statements included, *I keep a written list of “things to do”* and *I accept more tasks than I can complete*. Participants scored items on a 7-point scale relating to the degree to which the statements described them (1 = *extremely inaccurate* to 7 = *extremely accurate*). Negatively phrased statements were reverse coded. The scale was found to be highly reliable (Cronbach's $\alpha = .83$).

Propensity to plan scale. Planning was also measured using the propensity to plan scale (Lynch Jr., Netemeyer, Spiller, & Zammit, 2009); a scale measuring propensity to plan money and time. The present study used an abridged version, consisting of the 12 items relating to the planning of time (see Appendix J). Questions are split between 6 short-term (short run) statements, for example, *it makes me feel better to have my time planned out in the next few days*, and 6 long-term (long run) statements, for example, *I decide beforehand how my time will be used over the next 1-2 months*. Participants scored items on a 6-point scale relating to the degree to which the statements described their propensity to plan (1 = *strongly disagree* to 6 = *strongly agree*). The scale was found to be highly reliable (Cronbach's $\alpha = .92$).

Barratt impulsiveness scale. Last, impulsivity, the preference for speed over accuracy, was measured using the barratt impulsiveness scale (BIS-11; Patton & Stanford,

1995). This is a 30-item scale, scored using three sub-scales: attentional, motor and non-planning, with negatively phrased statements being reverse coded (see Appendix K). For example statements included, *I make-up my mind quickly* and *I am a careful thinker*. Participants scored items on a 4-point scale (1 = *rarely/never* to 4 = *almost always/always*). The scale is one of the most widely cited measure of impulsiveness, and was found to be highly reliable (Cronbach's $\alpha = .80$).

Results

Accuracy

The main dependent measure in the planning task was accuracy. Accuracy was calculated as the number of correct tasks selected, the maximum possible score being 16. Scores, reported in Table 1, suggest that participants in the high interactivity condition were more accurate than those in the low interactivity condition, with no effect of ego depletion. In a 2 x 2 between subjects analysis of variance (ANOVA) the main effect of interactivity was significant $F(1,96) = 78.03, p = < .001, \eta_p^2 = .448$, while neither the main effect of ego depletion $F < 1$, or the interaction $F < 1$ were significant.

Table 1

Mean Accuracy Scores and Standard Deviations by Condition

	Ego Depletion		Control	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Low	10.92	2.43	11.12	2.30
High	14.36	1.50	14.60	1.38

Total Latency

Total latency is shown in Table 2. In a 2 x 2 independent ANOVA the main effects of interactivity $F<1$, and ego depletion $F<1$ were non-significant, as was the interaction $F<1$.

Table 2

Mean Total Latency (in seconds) and Standard Deviations by Condition

	Ego Depletion		Control	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Low	530.56	143.60	610.40	262.40
High	528.92	168.12	557.04	136.70

Latency per Correct Task

Latency per correct task was calculated as total latency divided by accuracy; lower scores reflect better performance. Table 3 shows that generally participants in the interactivity condition were faster than those in the low interactivity conditions. A 2 x 2 independent ANOVA revealed a significant main effect for interactivity $F(1,96) = 25.72, p = < .001, \eta_p^2 = .211$. The main effect of depletion was not significant $F<1$, nor was the interaction $F<1$.

Table 3

Mean Latency per Correct Task (in seconds) and Standard Deviations by Condition

	Ego Depletion		Control	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Low	50.85	16.81	55.49	20.51
High	37.23	12.74	38.05	8.46

Note. Lower scores reflect better planning performance

Distractors

Number of distractors selected, described in Table 4, was not a main measure of performance, but are primarily reported in relation to assessment of the planning task itself. Generally participants in the low-interactivity condition selected more distractors overall, and the majority were non time-specific.

Table 4

Mean Number of Distractors Selected by Condition; Total, Time Specific and Non Time-specific

	High / Control	High / Depletion	Low / Control	Low / Depletion
	<i>M</i>	<i>M</i>	<i>M</i>	<i>M</i>
Total	22	27	70	76
Time specific	5	7	22	20
Non time-specific	17	20	48	56

Individual Differences

Flow. Based on previous research (e.g., Guthrie & Vallée-Tourangeau, 2015) it was expected that the attitude of participants would be more positive toward the high-interactivity condition. This was the case; independent *t*-tests showed that flow increased significantly as a function of interactivity level; high interactivity ($M = 48.82$, $SD = 6.50$), low interactivity ($M = 40.10$, $SD = 7.88$), $t(98) = 6.04$, $p < .001$.

Furthermore, in the high-interactivity condition flow was significantly positively correlated with accuracy $r(48) = .34$, $p = .015$. Flow was negatively correlated with latency per correct task $r(48) = -.29$, $p = .042$, indicating that as flow increased latency per correct task decreased. In the low-interactivity condition flow was negatively correlated with latency per correct task $r(48) = -.35$, $p = .014$.

Correlational analyses on total data revealed a significant positive relationship between flow and accuracy $r(98) = .50, p = < .001$. Negative relationships were found between flow and total latency $r(98) = -.21, p = .041$, latency per correct task $r(98) = -.48, p = < .001$, and impulsivity $r(98) = -.23, p = .024$.

Planning and impulsivity. Mean scores and standard deviations for the propensity to plan, planning survey and BIS scales are presented in Table 4. As participants were randomly allocated to the experimental conditions, we expected no difference between conditions on these measures and indeed there was none. There were no significant differences between scores in any of the four conditions⁶.

Table 5

Mean Scores and Standard Deviations by Condition for Propensity to Plan, Planning Survey, and BIS

	High / Control		High / Depletion		Low / Control		Low / Depletion	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Propensity – Short	24.96	8.01	25.40	7.22	24.84	7.619	25.44	5.94
Propensity – Long	21.68	6.64	21.68	7.35	20.24	7.06	21.16	7.60
Propensity - Total	46.64	13.40	47.08	12.35	45.08	12.96	46.60	12.34
Planning Survey	146.04	22.09	152.36	19.17	145.52	20.96	146.48	20.16
BIS	63.96	9.35	62.40	10.05	70.04	10.70	62.64	9.52

Note. Propensity = Propensity to plan

In order to assess the influence of individual differences on task performance, planning and impulsivity were correlated with the two significant performance measures; accuracy and latency per correct task. In the high-interactivity condition neither planning measure predicted planning performance. However, the correlation between accuracy and impulsivity was approaching significance $r(48) = .27, p = .058$. In the low-interactivity

condition, there were no significant correlations between performance and the planning survey or impulsivity. However, the correlation between accuracy and propensity to plan total was marginally significant $r(48) = .28, p = .050$ (see Figure 4).

Figure 4. Correlation between propensity to plan total and accuracy; low-interactivity condition (left panel), and high-interactivity condition (right panel).

As expected, correlational analyses on the total data revealed significant negative relationships between impulsivity and propensity to plan total $r(98) = -.27, p = .007$, and between impulsivity and the planning survey $r(98) = -.49, p < .001$. Intercorrelations among the planning measures were found between propensity to plan short term and propensity to plan long term $r(98) = .56, p < .001$, and between propensity to plan total and the planning survey $r(98) = .61, p < .001$.

Moderating effects of individual differences on ego depletion. To investigate the influence of individual differences on the strength of the ego-depletion effect, we analysed how effortful participants found the video task, and investigated strategies employed during the task by analysing performance on the video task memory test and video task questions; Table 6 presents the means scores and standard deviations.

Table 6

Mean Scores and Standard Deviations by Depletion Condition for Video Task Questions and Video Task Memory Test

	Ego Depletion		Control	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Video Task Q1	4.20	2.89	2.84	2.38
Video Task Q2	7.38	1.99	6.74	2.32
Video Task Q3	6.38	3.17	7.36	2.98
Video Task Q4	3.14	2.52	5.16	2.71
Video Task Q5	8.56	1.89	4.74	2.69
Video Task Memory Test	4.68	4.33	12.72	3.72

Note. Q1: “How difficult was it to perform the instructions you were given prior to watching the video?”, Q2: “Rate how much effort you put in to this task”, Q3: “Did you think we were going to ask you about the words later in the experiment?”, Q4: “When you saw the words on the video, how hard did you try to remember them?”, Q5 “When you saw the words on the video, how hard did you try to ignore the words?”

Effort. If the video task demanded more self-control in the depletion condition than in the control condition, then effort ratings should be higher in the depletion group (Lurquin et al., 2016). Depletion participants did indeed rate the video task as more effortful than the control participants, however the difference was non-significant, $t(98) = -1.48, p = .142$.

Strategies during the video task. To explore participants’ behaviour during the video task, and in particular those in the control condition, the video task memory test scores were analysed (Lurquin et al., 2016). Performance scores on the test were presumed to indicate whether participants followed the video task instructions for their condition. Participants in the depletion condition were instructed to ignore the words, so if they followed the instructions they should demonstrate lower recognition performance. This was the case:

Participants in the depletion condition showed significantly lower performance than those in the control condition $t(98) = 9.97, p = < .001$. This was consistent with the condition differences in how hard participants tried to remember the words on the screen $t(98) = 3.86, p = < .001$, and how hard they tried to ignore the words on the screen $t(98) = -8.23, p = < .001$ (see Table 5). Notably however, correlational analyses revealed no significant relationships between any of the above strategies and planning task performance across both conditions.

Qualitative Observations

To supplement the quantitative examination, we carried out an analysis of the verbal utterances of low-interactivity participants and the moves of high-interactivity participants.

Low-interactivity audio. Participants in the low-interactivity condition ($n = 50$) were audio recorded using a small Dictaphone placed on the desk. All participants consented to being recorded. Audio data from two participants was excluded due to poor sound quality. Analysis of the low-interactivity audio revealed that 41 out of 48 participants in the low-interactivity condition spoke out loud to themselves during the planning task. This did not significantly differ between ego-depletion conditions; ego-depletion condition ($n = 20$) control condition ($n = 21$). Participants who only uttered “um” or other non-words were excluded from the analysis.

The nature of these utterances varied from temporal reminders, for example:

OK so we're on Wednesday (P25)

So that's the Monday morning tasks (P32)

That's Monday afternoon done (P64)

Tuesday morning, let me see (P92)

Trying to find a task on the list:

Where did it go? (P24)

Where was the other thing, I've lost it (P48)

Where is that other one? (P41)

Have I done that, no (P76)

Difficulties with the task:

I just want to cross things off the list (P41)

I keep losing my place (P48)

I can't remember what I did on Monday now (P56)

Narrativizing the task:

I'll go for a walk whilst I think about this as it's very complicated (P57)

On Wednesday afternoon I'll go for a walk because I'm stressed that I didn't post my letter (P84)

High-interactivity video. In order to better understand the processes by which the high-interactivity condition supported participants to complete the planning task a random selection of participants ($n = 15$) were video recorded. Participants consented to being filmed and the cameras were positioned unobtrusively. The samples are not a systematic analysis of behaviour. Instead they represent the stages followed by a sample of participants who optimally utilised the affordances uniquely provided by the high interactivity condition, and achieved 100% accuracy on the task.

In the first image the participant lays out all the cards in order to read them before selecting any tasks. The majority of the high-interactivity participants laid out the cards in some format on the table. However two participants kept the cards in their hands for the duration of the task – dividing target and distractor cards using their fingers.

Figure 5. P79 lays out all the cards to read them.

Having read all the cards, participants next separated target cards from the distractors. This provided the high-interactivity participants with the opportunity to count the number of target cards they had selected before planning further. This initial accuracy check was only carried out by six out of 50 participants. In the example below, the discarded cards have been moved to the far left of workspace and the participant is counting to check that 16 target cards remain.

Figure 6. P54 counts the selected cards and creates a discard pile (on right of image).

Next participants took the opportunity to plan for the entire four days before finalising any cards on the board. Crucially time-specific cards were placed in the board first which afforded obvious gaps in the plan in to which non time-specific activities could be placed.

Figure 7. P47 Plans all four days on the desk before moving any cards to the day frame. Gaps are left into which non time-dependent tasks can be placed.

Finally, the plan for all four days was checked before choices for Monday were confirmed to the experimenter. As participants carried out this final check they typically touched the card to direct attention. Occasionally they also touched corresponding cards to ensure that all phases of the two and three stage activities had been completed. Cards planned for Monday were then moved to the day frame, followed by the remaining three days in turn.

Figure 8. P54 Touching cards to check them.

Discussion

The primary objectives of this experiment were to examine how the manipulation of interactivity level and ego depletion would affect planning performance in healthy adults. To examine these variables, a sequential-task paradigm was conducted. First, ego depletion was manipulated using a video-viewing task. This was immediately followed by a planning task, which varied the level of interactivity on a constant problem. The key finding of the study was a significant effect of level of interactivity on planning performance. The effect of level of ego depletion was never significant. The present study was conducted, in part, in response to the call from Lurquin et al. (2016) to examine the reliability of the ego-depletion effect. Thus, the secondary objective of this experiment was to investigate exactly what participants

were doing during the video-viewing task in order to understand better the ego-depletion effect. The results of both objectives are discussed below.

Interactivity

The effect of interactivity on planning was examined using three measures of performance; accuracy, latency, and latency per correct answer. Latency remained constant across both interactivity conditions. Generally, however, participants were more accurate and achieved faster latency per correct answer in the high-interactivity condition.

Accuracy and latency per correct answer. These results support our hypothesis, and add complementary evidence to the burgeoning work on interactivity (e.g., Guthrie & Vallée-Tourangeau, 2015; Vallée-Tourangeau, Guthrie, & Villejoubert, 2013) which demonstrates that a high interactivity environment scaffolds improved performance. These data can be explained in terms of the affordances provided by the different task environments. In the low-interactivity condition the static paper presentation and instructions to keep hands down resulted in an environment which participants could not shape or reorganise, severely limiting the interplay between cognitive and motor systems. Instead, they were forced to manipulate information mentally, relying on strategic, executive function-directed planning. As such, performance was limited by the capacities of working memory and other executive functions. Participants taking part in cognitive tests often use resourceful strategies to avoid loading working memory (Phillips & Forshaw, 1998). Indeed to facilitate performance in the low-interactivity condition the majority of participants (85%) utilised a self-talk strategy to verbally signpost temporal and task information (e.g., “That’s Monday afternoon done”). In this way, participants ameliorated performance by creating their own distributed feedback system (Clark et al., 2011). This was a strategy not utilised by the high-interactivity

participants; presumably it was not required since this information was provided by the distributed environment.

In contrast, the dynamic interface of the high-interactivity condition facilitated new affordances for task completion and paved the way for opportunistic planning, whereby solutions are revealed by interactivity rather than premeditation (Guthrie et al., 2015). Planning was interspersed with execution, placing less load on working memory compared to the complex initial planning in the head required by the low-interactivity constraints (Phillips et al., 2001). Thinking was supported by the environment, specifically by adaptive manipulation of the environment, enabling cognition to be extended beyond the internal resources of the participant. 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 the problem presentation in a way that was conducive to solving the task. This re-structuring was not just in order to set up an initial presentation of the problem, but (in general) a continuous process that remained dynamic until the solution was found.

Spatial arrangements. Reorganising the activity cards made it possible to collate items that had previously been distant. For example, the three cards representing the constituent parts of three-part activities could be physically grouped in order to simplify the problem. Kirsh (1995) suggests that spatial arrangements can scaffold thinking by simplifying choice, perception and internal computation, as well as by tracking the state of the task and predicting the effect of actions. Here the list format of the low-interactivity condition remained unmodifiable throughout the task. Participants were not allowed to cross off distractor activities, or those that they had already completed. Choices of activities that had already been completed had to be held in working memory. In contrast choice was

simplified in the high-interactivity condition; distractor cards could be discarded (see Figure 6) and previous choices of activities were available to be perceived on the execution board.

Participants were also able to track the state of the task at all times. For example, they are planning Tuesday and they have completed two tasks for the morning, having finalised Monday. Monitoring goal progress helps goal attainment (Harkin et al., 2015), and this enabled all participants in the high-interactivity condition to complete the required 16 tasks, while those in the low-interactivity condition completed between 13 and 20 tasks. Furthermore, in the hands-down condition predicting the effect of actions relied on complex internal computations, imagery and memory. Alternately, in the card condition rearranging cards was a simple, low-cost, physical movement. If the participant in this condition planned all time-specific tasks first, they could then perceive gaps left in the plan, thus placements for single item tasks were physically discovered (Kirsh, 2010). Overall, the actions available in the cards condition also provided guidance and direction for participants' attentional resources (Vallée-Tourangeau, Sirota, & Villejoubert, 2013), whereas low-interactivity participants were continually attracted to irrelevant or completed tasks.

Latency. There was no significant difference in latency between the two interactivity groups. In line with Guthrie, Harris, and Vallée-Tourangeau (2015) and Guthrie and Vallée-Tourangeau (2015) this suggests that improvements on other performance measures were associated with the mode of planning, rather than the time necessary to complete the plan. The stability of the cards' presentation may also offer an explanation for the parity of latency between groups. Upon apparent completion of the task, the low-interactivity participants had no way to double check their solution. It had been verbally described with no permanent record available to the participant. In the cards condition, once the planning had been completed the participant had the opportunity to go back to review and check their plan before confirming it as their final plan. Number of moves was not constrained, and given that

the instructions state no task time limit, it is feasible to suggest that the total latency in the high-interactivity condition did not reflect the speed with which participants could complete the task, but rather the speed at which they felt confident that they had completed the task accurately.

Flow. Individuals were more engaged in the planning task when they were given the opportunity to interact with it, rather than in the static condition. This pattern in level of engagement is found in the extant literature (e.g., Guthrie et al., 2015; Guthrie & Vallée-Tourangeau, 2015). However, unlike Guthrie, Harris, and Vallée-Tourangeau (2015) performance, as measured by accuracy, was also influenced by task engagement. The influence of flow on performance was different as a function of interactivity. Participants interacting with cards were both more engaged in the task and performed better, whereas in the hands down condition there was no correlation between accuracy and performance. It is likely that the reduced cognitive load of the high-interactivity condition, combined with the novel board game format, made this condition more fun and enjoyable to complete (Moyer, 2001). This supposition was reinforced by anecdotal comments made by the participants during the debriefing. Planning and striving for goals is an inherently affective experience, and attaining those goals provides satisfaction (Maglio et al., 2014). In the cards condition participants were able to visibly perceive that they had completed the goals and likely feel the associated satisfaction. This was not so for hands down participants. Further research should consider the role played by emotion in planning.

Individual differences. We sought to identify 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. Therefore participants were measured in terms of planning ability using both the propensity to plan and planning survey. In addition, the

BIS-11 was used to measure impulsivity; a speed/accuracy trade off which may result in thinking before acting behaviour that traditionally produces poor planning (Luciana et al., 2009). In the high-interactivity group, participants' performance was not determined by planning. However, impulsivity was related to accuracy on the planning task at a level approaching significance, whereas there was no significant relationship between the two in the low-interactivity. Instead, in the low-interactivity condition there was a more traditional relationship between planning performance and planning skills as measured by propensity to plan. The correlation between planning and performance in the low-interactivity condition suggests that participant performance reflected executively-controlled planning skills. In the high-interactivity condition the increased performance, combined with the lack of correlation between planning and performance, suggests that the manipulation of cards augmented the planning abilities of the high-interactivity participants, such that they were 31% more accurate than those in the static condition.

This pattern of relationships suggests that different types of skills were recruited in the high- and low-interactivity versions of the task. For participants who could not interact with the problem, performance was predicted by their planning ability. The static problem representation meant that participants had to rely on their internal cognitive abilities to solve the planning task (Vallée-Tourangeau & Villejoubert, 2013). Perceptual feedback from the problem representation remained the same for the duration of the task, and as such, all thinking and planning was confined to the head and its concomitant limitations. In contrast, the cards condition provided an environment that participants could exploit; physically manipulating cards to change and simplify the problem presentation. As illustrated in the qualitative analysis, generally the most accurate participants also made the greatest number of moves. For example, laying out cards to read them, discarding distractors, planning days before moving them to the execution board, etc. It is for this reason that we suggest that

planning performance in this condition was correlated with impulsivity. Further research is needed to examine this assertion, and a systematic analysis of the qualitative data was beyond the scope of the present study. Instead the qualitative results presented here were designed to highlight significant and recurrent patterns of observed behaviour. Future research should include systematic qualitative analysis since a triangulation of qualitative and quantitative analyses are essential in order to identify behaviours that can explain task success and failure (Steffensen, Vallée-Tourangeau, & Vallée-Tourangeau, 2016).

Ego Depletion

The present study also set out to examine the effect of ego depletion on planning using one particular combination of sequential tasks. Despite using a larger than average sample size ($N = 100$), and a highly-replicated depletion task, the predicted main effect of ego depletion, as reflected by lower performance in the planning task, was non-significant across all measures. This finding 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 have failed to detect the ego-depletion effect. Most notably Lurquin et al. (2016) which used the same initial video-viewing task in combination with a working memory span outcome task. To extend previous research, and attempt to explain the failure to detect ego-depletion, we followed Lurquin et al. (2016), and measured how participants behaved during the video task.

Participant adherence to instructions. We were interested in the potential moderating effect of how closely participants followed the instructions during the depletion task. In the video-viewing task, presumably if all participants followed the task instructions then those in the ego-depletion condition would exert self-control by ignoring the words

where those in the control condition would not. However participants in the control condition were not told about the words at all, despite their salience on the screen. It is therefore likely that participants selected different strategies in order to deal with the words with some trying to memorise the words and others ignoring them, perhaps even exerting a form of self-control to the same extent as the depletion condition.

There was no significant difference between conditions in the amount of effort participants put in to the task. This result was surprising since the amount of effort required to ignore the words should exceed that required in the control condition. If participants do not engage in effortful self-control in the video-viewing task, it is unlikely that they will be sufficiently depleted to show decrements in planning performance. Furthermore, the majority (82%) of control participants reported exerting some level of effort to ignore the words (at least 2 out of 10), despite receiving no instructions to do so. Just under half (42%) reported high levels of effort (between 6 and 10 out of 10), indicating that they likely exerted self-control akin to being in the ego-depletion condition.

If participants in the ego-depletion condition had followed instructions to ignore the words they would not remember any words. However, more than half (60%) the participants reported trying to remember the words (at least 2 out of 10) despite being told to ignore them. In fact, when tested in the video memory test, a large proportion (72%) remembered one or more word. These data suggest that participants in both conditions failed to adhere to task instructions. Thus the distinction between the two conditions was blurred, with some participants in the control condition exerting self-control and some in the depletion condition not doing so when they should have. However even when task performance was analysed in relation to these individual differences in task effort and adherence, no significant correlations were found. Overall there was no evidence that completion of the depletion task

led to reduced self-control, and even when these individual differences were controlled for there was no evidence for the ego-depletion effect.

The present study made every effort to replicate the original video-viewing paradigm designed by Schmeichel et al. (2003). To increase the likelihood of detecting the depletion effect, two key modifications were made. First, in order to minimise variation, the distance between participant and screen was standardised. Even though it is likely that sitting very close to the screen would allow participants to ignore the words with reduced effort, a standard distance had not been specified in previous studies. Second, the stimuli presentation was modified such that the distracting words were centred at the bottom of the screen rather than at the lower right. This served to avoid pseudoneglect; the natural inclination to over-attend to information on the left side of space (Nicholls, 2014), and to increase the saliency of the changing words. In turn this modification should have increased the amount of self-control required in order to avoid attending to the words literally at the centre of attention.

Explanations for failure to detect ego-depletion. Despite these modifications, and careful replication, the present study failed to detect the ego-depletion effect. Here we consider several possible explanations for this failure. First, a critical pre-requisite of the sequential-task paradigm is that both parts of the task require self-control. The present planning task was not one of the frequently used dependent tasks and, to our knowledge, has not previously been used in combination with a depleting task. Hence one possible explanation for the lack of observed effect is that the outcome planning task did not require self-control. Previous research has failed to define self-control clearly and to justify why some tasks require self-control and others do not (Lurquin et al., 2016). Some studies have even used the same task as the outcome self-control task (e.g., Stillman et al., 2009), and the control task assumed not to require self-control (e.g., Burkley, 2008). Nevertheless, there is little doubt that planning requires the deliberate control of actions across time, and

Baumeister and Vohs (2016) agree 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. However, given the multiplicity of variables extant research has shown to influence the ego-depletion effect size, the notion that self-control is a singular resource may be simplistic (Dubner, 2016). As such, the planning task may not draw on the same self-control resource as the initial task.

Second, given the glucose hypothesis explanation of ego depletion it is possible that food previously consumed could have affected the depletion effect, and future research should control for this factor. However, since this explanation is largely discredited it is unlikely to provide an explanation for failure to detect the ego-depletion effect. Another factor that may have affected detection is the time of day and the associated physical and cognitive load with which participants came to the task. Participants planning at the beginning of the day may have had an advantage over those who completed the task later after a busy and tiring day. Recent studies have found significant effects for time of day on decision making (Ingram et al., 2016) and implicit evaluations (Haynes, Kemps, & Moffitt, 2016), as well as immediate and sustained effects of exercise on planning (Hung, Tsai, Chen, Wang, & Chang, 2013). Future research should therefore control for these factors in order to increase the likelihood of detecting the ego-depletion effect.

Last, while other explanations may be advanced, the failure to detect ego-depletion in the present study may be due to it not being a reliable phenomenon. The present study is just one particular combination of tasks, and cannot therefore be generalised across other combinations. However given the results reported here, along with the other recent detection failures presently discussed, Carter and McCullough's (2014) suggestion that the effect has

been overestimated in the literature and is not significantly different from zero seems plausible.

Planning Task

Beyond the theoretical implications, the current findings may have many practical implications for areas such as business, medicine and other high-jeopardy planning settings. For this reason, we highlight certain limitations to the planning task along with recommendations for future research. Compared to many traditional planning paradigms, the present task had the advantage of simulating real-life activities that participants readily understood. They also reported to find the task enjoyable and engaging, particularly in the cards condition. However, the present results suggest some limitations associated with using such real-life tasks. Outside the laboratory planning does not take place in a vacuum, but utilises “stored preferences”; knowledge of previous similar situations and goals (Burgess et al., 2005). In the present task distractors were split between time-specific activities and non-time specific tasks. Since many of the target activities were time specific, presumably participants would be more likely to be distracted by time-specific activities. This was not the case, and on average participants selected 3 times as many non-time specific tasks, despite no mention of time on the summary card. The non-time specific tasks were activities often associated with planning a trip, for example, “buy a memory card for your camera” and “buy some suntan lotion from the pharmacy”. These data suggest that participants started to express stored preferences during the task rather than following the summary card. Designing tasks that require novel planning would ensure that stored preferences and the task instructions remain distinct.

For high-interactivity participants, the cards were handed to them in a randomly ordered pack. Between participants the cards were shuffled so that every participant received

a differently ordered pack. In the static condition, random ordering was not possible in the same way. Instead two different activities lists were alternated. No differences in performance were observed between lists. Both conditions used the same summary card, the order of which remained unchanged. The first item on the summary card was “you want to fly to Valencia”. The large majority (82%) of participants selected “call the travel agency to book the air flight tickets for your Friday trip to Valencia” on Monday, despite no day or time constraint on this task. The use of a second, differently ordered summary card would reveal whether participants selected this task first due its position on the summary card, or due to stored preferences.

The data presented here were generated on the basis of an interactive, dynamic cards version of the task and a hands-down, static, paper presentation. In the real world the participant would likely have the opportunity to exploit naturally occurring affordances from a pen and paper. The constraints of the present study restricted the affordances commonly associated with a paper presentation. However this condition simulated as closely as possible thinking in the head, rather than using paper and pencil which in itself configures an extended cognitive system. It could also be argued that the planning task itself provides unrealistic constraints since there were no unexpected events to react to such as the ones you would expect to find in real life. However while this task is necessarily constrained and artificial, the real-world nature of the problem combined with the interactive methodology employed provides a much closer illustration of real-life planning than static or transformation tasks (Vallée-Tourangeau & Villejoubert, 2013).

This study was developed to assess planning in healthy adults. It has added insight into how interactivity and ego depletion affect planning, thereby extending research that has previously focused on the cognitive deficits associated with frontal-lobe damage. Overall, ego depletion did not impact performance. These findings, when combined with other

recently obtained results, cast doubt on the ego-depletion effect and the strength model of self-control, and suggest further exploration is required to elucidate this elusive resource. Analysis of participant adherence during the video-viewing task revealed that the lines were often blurred between conditions, and as such this paradigm needs further iterations. The present experiment has also demonstrated that the complex cognitive process of planning can be successfully studied using a real-world interactivity-based approach, and can thereby yield insights into an ecological understanding of the cognitive processes involved in planning (Steffensen et al., 2016). The ability to plan was enhanced when participants were able to modify the problem space using real world artefacts. Conversely when those affordances for action were removed, restricting that task to a purely cognitive process, executive functions became belaboured and task performance diminished. The extended cognitive system created via interactivity supports working memory and focuses attention in a manner that scaffolds improved performance. Overall these findings suggest that an environment which fosters interactivity has the potential to augment an individual's planning abilities.

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Footnotes

¹ Freud's ego was responsible for balancing the inner needs of the id and superego within the context of society, and required energy to make decisions, accomplish task and resist the desires of the id and superego (Baumeister et al., 1998).

² Registered Replication Reports (RRRs) combine many replications that all follow an identical protocol in order to arrive at an unbiased estimate of effect size (Simons, Holcombe, & Spellman, 2014).

³ Downloaded from <https://psy.fsu.edu/~baumeisterticelab/egodepletion.html>.

⁴ The anamorphic nature of the original video has been corrected to suit modern video players, hence the discrepancy of the woman's shape.

⁵ Randomised on <https://www.randomizer.org/>.

⁶ Except for impulsivity there was a significant main effect for ego depletion $F(1,96) = 5.101, p = .026, \eta_p^2 = .050$.

Appendix A: Demographics Questionnaire

The following questions are designed to provide some basic background information to help with the study. All information obtained will be confidential.

Please complete or circle as appropriate

Age:

Gender: Male / Female

Level of education achieved: No qualifications / GCSEs / A-levels / Degree / Postgraduate or above

I am a fluent English speaker and writer: Yes / No

I have normal or corrected-to-normal vision (i.e., you are wearing glasses today if you need them): Yes / No

I do / do not (circle as appropriate) suffer from any neurological disorders or take any medication that would affect my problem solving abilities.

Appendix B: Video Viewing Instructions

Ego-Depletion Condition

“This experiment investigates how people form impressions of others and how those impressions influence memory. So, I’m going to have you watch a short film clip that shows a woman being interviewed, but I’m going to turn the sound off so that you can only see the woman. Later I’ll have you answer some questions about your impressions of her. Since you won’t be able to hear what she’s saying you’ll have to base your impressions of her on her nonverbal behaviour.

So, in addition to the woman being interviewed, you will also see some words on the bottom of the screen. It is very important for the purposes of this experiment that you keep your attention focused only on the woman’s face and do not look down at the words that appear at the bottom of the screen. If you do accidentally look at the words, I want you to re-focus your attention on the woman as quickly as possible.

This task may be kind of difficult because the words take up a decent portion of the screen, but I want you to try hard to ignore these words and focus your attention only on the woman. Later, you’ll have to answer some questions about your impressions of the woman based on her nonverbal behaviour. When the clip ends, let me know. Remember, focus only on the woman and try to ignore the words”.

Control Condition

“This experiment investigates how people form impressions of others and how those impressions influence memory. So, I’m going to have you watch a short film clip that shows a women being interviewed, but I’m going to turn the sound off so that you can only see the woman. Later I’ll have you answer some questions about your impressions of her. Since you won’t be able to hear what she’s saying you’ll have to base your impression of her on her nonverbal behaviour.

When the interview clip starts, I want you to watch it just as if you were sitting at home watching TV, even though the sound will be off. I don’t want you to worry about try real hard to form an impression or anything. Just watch the clip and when it ends, let me know”.

Appendix C: Planning Task Summary Card

These are the tasks that you need to achieve before your trip.

YOU CANNOT USE A MOBILE PHONE OR INTERNET. You can only achieve your goals using the cards on the board / the options from the activities list. No other strategies or assumptions can be made.

- You want to fly to Valencia
- You want to make sure that your smart clothes are safe by putting them in the overhead compartment on the plane but you do not have a carry-on suitcase
- Your trip is short and you want to make sure you know where all the top attractions are
- You need to get some Euros to pay for a taxi when you arrive at Valencia airport
- Your friend knows all the best places to eat in Valencia and has promised to tell you about them over dinner
- The play you'd like to see is selling out fast. Your only chance to get tickets is from the box office
- You have written a letter to an old friend that needs to be posted before you leave
- You want to ensure your utilities are not cut off while you are away

Appendix D: Planning Task Activities List

Single activities

- (A1) Pay your electricity bill. This has to be done by Friday or you will be cut off
- (A2) Pay your telephone bill by Friday
- (A3) On Monday afternoon go to your friend's house to borrow a guide book you will need for your trip (TSA)
- (A4) Go to the bank to get some Euros for your trip. This has to be done on Thursday (TSA)

Two-part activities

Get the flight tickets for the Friday trip to Valencia:

- (B1) Call the travel agency to book the air flight tickets for your Friday trip to Valencia
- (B2) On Thursday morning go to the travel agency to collect your flight tickets (TSA)

Post a letter to a friend:

- (C1) Buy the envelope you will need to send your letter
- (C2) Go to the Post Office to send your letter on Wednesday morning (TSA)

Get some tickets to go to the theatre:

- (D1) Telephone the theatre box office to book your tickets for the Wednesday night play
- (D2) Collect your theatre tickets from the box office on Wednesday morning (TSA)

Three-part activities

Get clothes packed for the trip:

- (E1) Pick up your smart clothes from the dry cleaners that you have to take on your trip
- (E2) Buy a suitcase you will need for the trip
- (E3) Pack your clothes on Thursday afternoon (TSA)

Organise dinner for a friend:

- (F1) The dinner with your friend is on Tuesday night. Call your friend to give him/her directions to get to your place
 - (F2) Buy what you need to cook for the Tuesday night dinner with your friend
 - (F3) Cook the meal for the dinner with your friend. You should do this on Tuesday afternoon in time for the evening (TSA)
-

Appendix E: Planning Task Instructions

Low-Interactivity Condition

You are going to complete a planning task which involves planning an overseas trip. At the end of the week, which is Friday, you are going to Valencia. The aim of the task is to organise and carry out a series of activities that prepare you for the trip. You need to complete these by the end of Thursday.

This is the task summary card. This specifies the activities that need to be completed in preparation for your trip. The summary card will be available to you for the duration of the task. All tasks are of equal importance and you cannot use any strategies that you may use outside this room. Please read the summary card.

You have 4 days to carry out the tasks specified on the summary card – from Monday to Thursday. You carry out 4 tasks per day – 2 in the morning and 2 in the afternoon. You will carry out activities one day at a time starting with Monday. I will give you a list of activities. From this you will plan which activities you will carry out on each day from Monday to Thursday. Then starting with Monday you will tell me which 2 activities you will carry out in the morning and which 2 you will carry out in the afternoon and I will note them down. You can then move on to the next day.

Do you have any questions?

There are 4 important rules:

- Not all activities on the activities list I'm about to give you can be completed. The challenge is to complete the ones that have to be done according to the summary card.
- There are some activities that can only be done at a particular time. This will be noted in the activity description.
- Once you have selected the 4 tasks for the day and told me your selection you cannot change this.
- You may not touch or point at the activities list. Please keep your hands on the table at all times.

Do you have any questions?

You will be timed during this task. There is no limit but please complete it as quickly and as accurately as you can. You may start now.

High-Interactivity Condition

This is the section of the study during which you will be filmed. I am going to switch on the camera now.

You are going to complete a planning task, in the form of a board game, which involves planning an overseas trip. At the end of the week which is Friday you are going to Valencia. The aim of the task is to organise and carry out a series of activities that prepare you for the trip. You need to complete these by the end of Thursday.

This is the task summary card. This specifies the activities that need to be completed in preparation for your trip. The summary card will be available to you for the duration of the task. All tasks are of equal importance and you cannot use any strategies that you may use outside this room. Please read the summary card.

You have 4 days to carry out the tasks specified on the summary card - from Monday to Thursday. You carry out 4 tasks per day – 2 in the morning and 2 in the afternoon. You will carry out activities one day at a time starting with Monday. Each activity is written on a playing card. Activities are “carried out” by placing the relevant playing card in the central boxes marked AM and PM.

Once you have put your 4 cards for Monday in to the central section, please let me know and I will move them to this side board. The side board is a record of activities you have already completed. You can then move on to the next day.

Do you have any questions?

There are 3 important rules:

- Not all activities on the cards can be completed. The challenge is to complete the ones that have to be done according to the summary card.
- There are some activities that can only be done at a particular time. This will be noted in the activity description on the card.
- Once you have selected the 4 tasks for the day and placed them on the board you cannot change this.

Do you have any questions?

You will be timed during this task. There is no limit but please complete it as quickly and as accurately as you can. You may start now.

Appendix F: Flow Scale

Thinking about the task you have just completed please circle the response that **best** describes how you felt while working on the problem.

1. Were you able to concentrate well on the task?

Definitely NOT								Definitely YES
0	1	2	3	4	5	6	7	

2. Did you find the task interesting?

Definitely NOT								Definitely YES
0	1	2	3	4	5	6	7	

3. Did you enjoy what you were doing?

Definitely NOT								Definitely YES
0	1	2	3	4	5	6	7	

4. Did you feel challenged by the task?

Definitely NOT								Definitely YES
0	1	2	3	4	5	6	7	

5. Did you feel skillful while working on the task?

Definitely NOT								Definitely YES
0	1	2	3	4	5	6	7	

6. Did you feel distracted while working on the task?

Definitely NOT								Definitely YES
0	1	2	3	4	5	6	7	

7. Did you feel relaxed while working on the task?

Definitely NOT					Definitely YES		
☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

8. Did you feel focused while working on the task?

Definitely NOT					Definitely YES		
☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

9. Did you feel anxious while working on the task?

Definitely NOT					Definitely YES		
☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

Appendix G: Word Memory Task

Ego-Depletion Condition**UNCONSCIOUS MEMORY TEST**

INSTRUCTIONS: Sometimes we unconsciously remember things that we don't realise we've seen. Some of these words were in the video that you watched earlier. Some of the words are new and you have not seen them in any of the tasks today.

Please circle YES or NO to indicate whether you remember seeing the word on screen during the video.

Kite	Yes	No	Bill	Yes	No
Winter	Yes	No	Tire	Yes	No
Table	Yes	No	Hair	Yes	No
Crutch	Yes	No	Sky	Yes	No
Perfume	Yes	No	Thumb	Yes	No
Boot	Yes	No	Snowman	Yes	No
Beer	Yes	No	Bagel	Yes	No
Shoe	Yes	No	Cane	Yes	No
Taxi	Yes	No	Coat	Yes	No
Disk	Yes	No	Rowboat	Yes	No
Straw	Yes	No	Pole	Yes	No
Uncle	Yes	No	Pulse	Yes	No
Show	Yes	No	Path	Yes	No
Blue	Yes	No	Car	Yes	No
Ping	Yes	No	Glue	Yes	No
Dentist	Yes	No	Stem	Yes	No
Hat	Yes	No	Hill	Yes	No
Gum	Yes	No	Spleen	Yes	No

Control-Condition**MEMORY TEST**

INSTRUCTIONS: Some of these words were in the video that you watched earlier. Some of the words are new and you have not seen them in any of the tasks today.

Please circle YES or NO to indicate whether you remember seeing the word on screen during the video.

Kite	Yes	No	Bill	Yes	No
Winter	Yes	No	Tire	Yes	No
Table	Yes	No	Hair	Yes	No
Crutch	Yes	No	Sky	Yes	No
Perfume	Yes	No	Thumb	Yes	No
Boot	Yes	No	Snowman	Yes	No
Beer	Yes	No	Bagel	Yes	No
Shoe	Yes	No	Cane	Yes	No
Taxi	Yes	No	Coat	Yes	No
Disk	Yes	No	Rowboat	Yes	No
Straw	Yes	No	Pole	Yes	No
Uncle	Yes	No	Pulse	Yes	No
Show	Yes	No	Path	Yes	No
Blue	Yes	No	Car	Yes	No
Ping	Yes	No	Glue	Yes	No
Dentist	Yes	No	Stem	Yes	No
Hat	Yes	No	Hill	Yes	No
Gum	Yes	No	Spleen	Yes	No

Appendix H: Video Scale

INSTRUCTIONS: Read each statement and then circle the appropriate number. Do not spend too much time on any statement. Answer quickly and honestly.

On a scale of 1 to 10, with 1 being NOT AT ALL DIFFICULT and 10 being VERY DIFFICULT , rate how difficult it was to perform the instructions you were given prior to watching the video.									
1	2	3	4	5	6	7	8	9	10
Not at all difficult								Very difficult	
On a scale of 1 to 10, with 1 being NONE and 10 being A LOT , rate how much effort you put in to this task.									
1	2	3	4	5	6	7	8	9	10
None								A lot	
On a scale of 1 to 10, with 1 being NOT AT ALL and 10 being ABSOLUTELY , did you think we were going to ask you about the words later in the experiment?									
1	2	3	4	5	6	7	8	9	10
Not at all								Absolutely	
On a scale of 1 to 10, with 1 being NOT AT ALL and 10 being A LOT , when you saw the words on the video, how hard did you try to remember them?									
1	2	3	4	5	6	7	8	9	10
Not at all								A lot	
On a scale of 1 to 10, with 1 being NOT AT ALL and 10 being A LOT , when you saw the words in the video, how hard did you try to ignore the words?									
1	2	3	4	5	6	7	8	9	10
Not at all								A lot	

Appendix I: Planning Survey (D. Simons & Galotti, 1992)

INSTRUCTIONS: Listed below are statements pertaining to planning styles. Using the scale below, please rate the degree to which each of the following statements describes you. Do NOT use decimals or fractions.

Extremely Inaccurate	Moderately Inaccurate	Slightly Inaccurate	Neither Accurate Nor Inaccurate	Slightly Accurate	Moderately Accurate	Extremely Accurate
1	2	3	4	5	6	7

1. _____ I write down appointments and meetings on a calendar.
2. _____ I keep a written list of "things to do."
3. _____ I forget to complete assignments by the date I need to.
4. _____ I think of alternative ways of getting a task done before I start doing it.
5. _____ I have a good feel for how long a task will take.
6. _____ I have a written list of goals for each day.
7. _____ I worry about the details of a task I'm doing.
8. _____ I finish a task at the last minute, with little time to spare.
9. _____ I agree to perform a new task, without looking at what else I have already planned.
10. _____ I break a goal into parts or sub-goals.
11. _____ I budget my time.
12. _____ I put things off.

13. _____ I figure out how to accomplish a task ahead of time.
14. _____ I organize my materials for a task.
15. _____ I develop a system for getting things done.
16. _____ I have a good idea of which tasks are the most important for me.
17. _____ I leave myself "free time" in my schedule.
18. _____ I accomplish most of what I set out to.
19. _____ I have specific goals for the next five years.
20. _____ I make outlines for long papers or speeches.
21. _____ I make deliberate choices about future events.
22. _____ I run out of money by the end of the week or month.
23. _____ I think ahead.
24. _____ I see myself as disorganized.
25. _____ I do (or did) schedule courses ahead for the next few years.
26. _____ I have a morning or evening routine.
27. _____ I give myself a monetary budget.
28. _____ I anticipate conflicts ahead of time.
29. _____ I carry a "daily reminder" book.
30. _____ I accept more tasks than I can complete.
31. _____ I often blurt out things before I've thought them through.

Appendix J: Propensity to Plan Scale (LynchJr. et al., 2009)

INSTRUCTIONS: Read each statement and circle the appropriate number on the right side of this page. Do not spend too much time on any statement. Answer quickly and honestly.

1	2	3	4	5	6
Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree

Propensity to plan for time – short run:

1	I set goals for the next few days for what I want to achieve with my time	1	2	3	4	5	6
2	I decide beforehand how my time will be used in the next few days	1	2	3	4	5	6
3	I actively consider the steps I need to take to stick to my time schedule the next few days	1	2	3	4	5	6
4	I consult my planner to see how much time I have left for the next few days	1	2	3	4	5	6
5	I like to look to my planner for the next few days in order to get a better view of using my time in the future	1	2	3	4	5	6
6	It make me feel better to have my time planned out in the next few days	1	2	3	4	5	6

Propensity for plan for time – long run:

1	I set goals for the next 1-2 months for what I want to achieve with my time	1	2	3	4	5	6
2	I decide beforehand how my time will be used in the next 1-2 months	1	2	3	4	5	6
3	I actively consider the steps I need to take to stick to my time schedule in the next 1-2 months	1	2	3	4	5	6
4	I consult my planner to see how much time I have left for the next 1-2 months	1	2	3	4	5	6
5	I like to look to my planner for the next 1-2 months in order to get a better view of using my time in the future	1	2	3	4	5	6
6	It makes me feel better to have my time planned out in the next 1-2 months	1	2	3	4	5	6

Appendix K: Barratt Impulsiveness Scale (Patton & Stanford, 1995)

INSTRUCTIONS: People differ in the ways they act and think in different situations. This is a test to measure some of the ways in which you act and think. Read each statement and circle the appropriate number on the right side of the page. Do not spend too much time on any statement. Answer quickly and honestly.					
	1 Rarely / Never	2 Occasionally	3 Often	4 Almost Always / Always	
1	I plan tasks carefully.	1	2	3	4
2	I do things without thinking.	1	2	3	4
3	I make up my mind quickly.	1	2	3	4
4	I am happy-go-lucky.	1	2	3	4
5	I don't "pay attention".	1	2	3	4
6	I have "racing" thoughts.	1	2	3	4
7	I plan trips well ahead of time.	1	2	3	4
8	I am self-controlled.	1	2	3	4
9	I concentrate easily.	1	2	3	4
10	I save regularly.	1	2	3	4
11	I "squirm" at plays or lectures.	1	2	3	4
12	I am a careful thinker.	1	2	3	4
13	I plan for job security.	1	2	3	4
14	I say things without thinking.	1	2	3	4
15	I like to think about complex problems.	1	2	3	4
16	I change jobs.	1	2	3	4
17	I act "on impulse".	1	2	3	4
18	I get easily bored when solving thought problems.	1	2	3	4
19	I act on the spur of the moment.	1	2	3	4
20	I am a steady thinker.	1	2	3	4
21	I change residences.	1	2	3	4
22	I buy things on impulse.	1	2	3	4
23	I can only think about one thing at a time.	1	2	3	4
24	I change hobbies.	1	2	3	4
25	I spend or charge more than I earn.	1	2	3	4
26	I often have extraneous thoughts when thinking.	1	2	3	4
27	I am more interested in the present than the future.	1	2	3	4
28	I am restless at the theatre or lectures.	1	2	3	4
29	I like puzzles.	1	2	3	4
30	I am future-orientated.	1	2	3	4