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# A dual systems account of visual perception: Predicting candy consumption from distance estimates

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ABSTRACT

A substantial amount of evidence shows that visual perception is influenced by forces that control human actions, ranging from motivation to physiological potential. However, studies have not yet provided convincing evidence that perception itself is directly involved in everyday behaviors such as eating. We suggest that this issue can be resolved by employing the dual systems account of human behavior. We tested the link between perceived distance to candies and their consumption for participants who were tired or depleted (impulsive system), versus those who were not (reflective system). Perception predicted eating only when participants were tired (Experiment 1) or depleted (Experiments 2 and 3). Furthermore, a rational determinant of behavior—eating restraint towards candies—predicted eating only for non-depleted individuals (Experiment 2). Finally, Experiment 3 established that perceived distance was correlated with participants' self-reported motivation to consume candies. Overall, these findings suggest that the dynamics between perception and behavior depend on the interplay of the two behavioral systems.

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**PsycINFO classification**

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## 1. Introduction

Researchers have traditionally assumed that visual perception is shaped by objective physical properties of the environment (Marr, 1982; Michaels & Carello, 1981). For example, how a person sees a plate of food on a dining table was considered to be determined by factors such as the angle at which the surface of this object reflects light. However, during the past two decades, researchers have produced a substantial number of findings showing that behaviorally relevant factors, including motivation (e.g. Balcetis & Dunning, 2006; Krpan & Schnall, 2014a) and one's ability to act (e.g. Bhalla & Proffitt, 1999; Proffitt, 2006; Schnall, Zadra, & Proffitt, 2010), impact the perception of everyday stimuli. For example, in a landmark study, Bhalla and Proffitt (1999) showed that people who wore a heavy backpack, and whose capacity to climb a challenging hill was thus reduced, saw this hill as steeper compared to physically unburdened people. Therefore, to understand how people perceive their surroundings, it is necessary to grasp not only objective forces such as light but also subjective physiological and psychological states.[1]

Given a large body of evidence showing that behaviorally relevant bodily states influence perception (for reviews, see Proffitt, 2013; Schnall, in press-a), one would also expect that perception is directly related to everyday behaviors such as eating, walking, or shopping. However, this relationship has been observed in very few cases, primarily in the domain of physical activity and sports (Cole, Riccio, & Balcetis, 2014; Witt & Proffitt, 2005). For example, Witt and Proffitt (2005) showed that baseball players' perception of ball size was correlated with their batting average: players who hit the ball more successfully in a previous game perceived it as larger compared to those who were not as successful. However, in the domain of motivated behaviors towards rewarding stimuli such as food or money, no direct relationship between perception and actions such as eating or shopping has been observed (see Balcetis, 2016; Krpan & Schnall, 2014a). Overall, although numerous researchers showed that behaviorally relevant forces, including motivation and potential for action, shape per-

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ception, it has not been convincingly demonstrated that perception is linked to behavior. To identify a potential reason behind this discrepancy, it is first necessary to gain a deeper insight into the differential forces shaping human behavior.

### 1.1. Understanding human behavior: The dual systems account

One of the most widely adopted approaches to understanding behavior, known as the dual systems account, posits that human actions are shaped by two distinct processes (Kahneman, 2003, 2011; Marteau, Hollands, & Fletcher, 2012; Metcalfe & Mischel, 1999; Stanovich & West, 2000; Strack & Deutsch, 2004). On the one hand, people sometimes act spontaneously, without much thinking, based on their immediate intuitions, feelings, and motivations.[2] For example, a person might be offered candies at a party and eat them because s/he feels like doing so, without thinking about the potential health-related implications. Researchers jointly refer to intuitive and motivational processes that guide such behavior as the impulsive system (Dolan et al., 2012; Kahneman, 2003; Stanovich & West, 2000; Strack & Deutsch, 2004).[3]

However, people do not always act based on their feelings and motivations; they also think carefully about the consequences of an action, and it is through this deliberate decision making process that they decide whether to do something or not (Hofmann, Friese, & Strack, 2009; Kahneman, 2003, 2011; Stanovich & West, 2000). For example, a person offered candies at a party may feel like eating them but then decide not to do so because of potential negative health consequences. Alternatively, s/he may decide to eat them after weighing different pros and cons and rationally concluding that, given an active physical lifestyle, eating candies will not negatively impact her/his health. These and other rational processes that guide behavior are jointly referred to as the reflective system (Dolan et al., 2012; Kahneman, 2003; Stanovich & West, 2000; Strack & Deutsch, 2004; Vohs, 2006).

Given that the impulsive and reflective systems control behavior through different routes, their impact on human actions depends on the circumstances in which these actions take place. The impulsive system commands behavior when people's capacity to think rationally is reduced, which usually happens when they are tired and depleted, or when they need to act quickly (Hofmann, Friese, & Strack, 2009; Kahneman, 2003, 2011). Under these conditions people are more likely to rely on their feelings and motivations because it is too costly to engage in elaborate decision making or to resist one's temptations. In contrast, whenever the capacity for rational thinking is high, which is usually the case when people are rested and have not previously engaged in cognitively taxing activities (Hofmann, Friese, & Strack, 2009), reflective processes take over. These assumptions have been supported by numerous studies (Hofmann, Friese, & Strack, 2009; Hofmann, Friese, & Wiers, 2008; Vohs, 2006; Vohs & Faber, 2007). For example, Hofmann, Rauch, and Gawronski (2007) examined conditions under which the impulsive system (automatic liking of candies as measured via an implicit association test) and the reflective system (dietary restraint standards) guide eating of candies. They showed that, after people engaged in an effortful activity that depleted them, eating was predicted by their automatic liking of candies but not by the dietary restraint standards: stronger liking was linked to increased consumption. However, when people were not depleted, eating was predicted by their dietary restraint standards but not by automatic liking: those who classified themselves as restrained eaters ate less compared to unrestrained eaters. Therefore, situational circumstances determine the impact of the impulsive versus reflective processes on behavior.

### 1.2. The dual systems account and the perception-behavior link

Given that the dual systems account can explain a variety of everyday actions, this approach to understanding human behavior can also be used to clarify when exactly the perception-behavior link should occur. One important insight stemming from this account is that all physiological and psychological determinants of behavior that were shown to impact visual perception can be categorized as impulsive rather than reflective processes (see Balcetis, 2016; Balcetis & Lassiter, 2010; Krpan & Schnall, 2014a; Proffitt, 2006; Proffitt & Linkenauger, 2013). Indeed, constructs such as motivation (e.g. Balcetis & Dunning, 2010; Krpan & Schnall, 2014a) or physiological potential (Proffitt, 2006; Schnall et al., 2010) are usually not associated with reasoning and rational thinking. To our knowledge, no research has yet shown that people can deliberately change their visual perception of the surroundings by changing their reasoning about objects (see Proffitt, 2013; Schnall, in press-a), which would correspond to a "reflective" impact on perception. Therefore, it is plausible that visual perception is shaped by the impulsive system but not by the reflective system.

Based on this notion, we posit that visual perception might be directly related to behavior only when this behavior is shaped by impulsive forces, but not when the reflective system takes over. To clarify this assumption, we use two different behaviors as an example: hitting a baseball (Witt & Proffitt, 2005) and eating candies (Hofmann et al., 2007). When hitting a baseball, players cannot rely on their reflective system because the ball travels too quickly to afford rational decision making, and this behavior by default relies on automatic processes driven by skill and previous experience (see Kahneman, 2003, 2011). Therefore, because the impulsive system guides both perception and behavior in this case, these two variables should be correlated, and seeing the ball as larger should be associated with a better batting average, as Witt and Proffitt (2005) indeed demonstrated.

However, capturing a direct link between perception and behavior becomes more difficult when the behavior of interest can be guided by either the impulsive or reflective system, as is the case with candy consumption (Hofmann, Friese, & Strack, 2009; Hofmann et al., 2007). Indeed, as reviewed above, for some people (e.g. those who are depleted because of previously engaging in cognitively costly activities), eating is shaped by components of the impulsive system linked to affect and motivation (Hofmann, Friese, & Strack, 2009). However, for those who are rested, eating is controlled by rational determinants such as dietary restrains standards (Hofmann et al., 2007). Because visual perception (e.g. perceived size or distance) of rewarding stimuli such as candies is

[1] In the present manuscript, we use the term visual perception synonymously with "what is seen" (Pylyshyn, 1999; p. 343). According to Pylyshyn (1999, 2003), how people see the world is determined by the interaction of early vision—a basic process involved in encoding the image directly from the eye—and later processing stages that are influenced by information from long-term memory and other cognitive systems. It is currently a point of debate whether early vision itself can be influenced by subjective physiological and psychological states, or whether this influence occurs only at later processing stages (Lupyan, 2015). Hence, it is important to point out that in the present article we do not claim that psychological states influence early vision itself; their impact on what people see may occur at later processing stages, which does not conflict major theories of perception (Pylyshyn, 1999).

[2] In the present manuscript, we use the term motivation when referring to urges that are regulated by the brain's reward system (e.g. Berridge, 2009; Berridge, Robinson, & Aldridge, 2009; Kelley, 2004; Robbins & Everitt, 1996) and which most commonly occur in relation to rewarding stimuli such as sugary food, money, etc. In that sense, motivation is an intuitive rather than rational process and can be classified as an impulsive determinant of behavior (e.g. Strack & Deutsch, 2004).

[3] Not all dual systems theorists use the same terminology when referring to the two systems that guide human behavior. Indeed, some refer to the impulsive system (Strack & Deutsch, 2004) as System 1 (e.g. Kahneman, 2003; Stanovich & West, 2000) or hot system (Metcalfe & Mischel, 1999), whereas some refer to the reflective system (Strack & Deutsch, 2004) as System 2 (e.g. Kahneman, 2003; Stanovich & West, 2000) or cool system (Metcalfe & Mischel, 1999). Here we use the term the impulsive (reflective) system synonymously with different terms common in dual systems literature such as System 1 (System 2) or the hot (cool) system.

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guided by motivational states linked to the impulsive system (Balcetis, 2016; Krpan & Schnall, 2014a), a direct relationship between perception and candy consumption should occur only when impulsive processes determine this behavior, but not in other instances. Therefore, when it comes to actions that can be impacted by either the impulsive or reflective system and are in that sense similar to candy consumption, it may be difficult to capture the relationship with perception without understanding situational circumstances.

### 1.3. Overview of the present research

Overall, the literature suggests that perception should predict action only under circumstances that foster the impulsive system. To test this prediction, we selected a simple behaviour that can be influenced by either the impulsive or reflective system—candy consumption (Hofmann, Friese, & Strack, 2009). Furthermore, we operationalized perception as perceived distance to the candies, given that this measure was impacted by subjective motivational states in previous research (see Balcetis, 2016; Krpan & Schnall, 2014a). Therefore, in three studies we investigated the link between perceived distance to candies and their consumption. More precisely, In Experiment 1, we probed the relationship between distance estimates and eating for people who were tired (the impulsive system) vs. rested (the reflective system). In Experiment 2, we experimentally manipulated the strength of the impulsive versus reflective system by employing the ego-depletion paradigm (Baumeister, Bratslavsky, Muraven, & Tice, 1998) and tested the relationship between perceived distance to candies and their consumption for ego-depleted and control participants. Moreover, we measured their eating restraint regarding the candies to ascertain that eating in the control, but not in the depletion condition, was indeed shaped by the reflective system. Finally, in Experiment 3, we again probed the link between perceived distance regarding candies and eating under ego-depletion, to replicate the findings from Experiment 2. Furthermore, we assessed participants' self-reported motivation to eat the candies to further verify the connection between the impulsive system, perception, and eating.

## 2. Experiment 1

The aim of Experiment 1 was to provide preliminary evidence in support of the notion that perception predicts candy consumption when the impulsive system is enhanced. Given that being tired is usually associated with diminished cognitive capacity and related processes linked to the impulsive system (e.g. Alhola & Polo-Kantola, 2007; Mead, Baumeister, Gino, Schweitzer, & Ariely, 2009), we investigated the link between distance estimates and eating of candies under different levels of being tired versus awake. Therefore, we first assessed participants' perceived distance to candies without subjecting them to any experimental manipulation, and subsequently they engaged in the taste evaluation task where their candy consumption was measured (Hofmann & Friese, 2008; Hofmann, Friese, & Roefs, 2009; Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008; Hofmann et al., 2007). Finally, self-reported awake-tiredness was measured (Schimmack & Grob, 2000). Given the association between tiredness and the impulsive system, we predicted that perceived distance to candies would be related to the amount of candies consumed only for tired participants but not for those who are awake.

Importantly, what should be the direction of this relationship? Although researchers generally agree that the perception of rewarding stimuli such as candies is driven by motivation (see Balcetis, 2016; Krpan & Schnall, 2014a), findings disagree on whether this impulsive force should make the stimuli look closer or further away. For example, Balcetis and Dunning (2010) showed that desirable stimuli (vs. undesirable ones) are perceived as closer, presumably because this perceptual bias energizes the person to obtain them, which suggests that stronger motivation should make objects look closer. Therefore, based on this notion, one would expect that tired participants who see the candies as closer would subsequently eat more, given that perceived proximity may reflect increased motivation to consume the stimuli.

However, Krpan and Schnall (2014a) obtained dissimilar findings. They investigated how increasing the motivation to acquire rewards such as sugary foods (i.e., "approach") influences perceived distance to these stimuli compared to decreasing the motivation to attain them (i.e., "avoidance"; see Strack & Deutsch, 2004). Approach motivation was induced via arm flexion—an arm movement linked to pulling rewarding objects towards oneself—whereas avoidance was induced via arm extension—an arm movement associated with pushing a stimulus away from oneself (Cacioppo, Priester, & Berntson, 1993). The results showed that avoiding rewards made them appear as closer compared to approach. The authors argued that this perceptual bias occurred because, from an evolutionary perspective, avoidance is an unusual response to rewards (see Kenrick & Shiota, 2008; Strack & Deutsch, 2004; Youngstrom & Izard, 2008) and thus creates a state of cognitive inconsistency that makes the stimuli appear as closer. According to this rationale, perception has an adaptive role of signalling discrepancies between the person and the environment in order to minimize the chance of suboptimal outcomes. Indeed, throughout human evolutionary past, sugary foods that provide energetic resources were scarce, and avoiding (rather than approaching) them would have been maladaptive (Kenrick & Shiota, 2008; Youngstrom & Izard, 2008). Therefore, perceptual proximity regarding these stimuli may signal the incompatible motivational state of avoidance that corresponds to reduced inclination to eat (Förster, 2003). In contrast, an increase in perceive distance may occur under the strong inclination to approach rewards—a motivational state that may have been evolutionary advantageous in ensuring survival and thus corresponds to an absence of the person-environment discrepancy. In sum, according to Krpan and Schnall (2014a), seeing candies as farther (rather than closer), may reflect enhanced motivation to consume the stimuli, thus predicting increased eating under impulsive conditions.

Overall, given the conflicting findings on the direction of the relationship between impulsive processes and perception, we did not have a clear prediction regarding the expected direction of the relationship between perceived distance to candies and their consumption for tired participants.

### 2.1. Method

#### 2.1.1. Participants

One hundred and ten participants (66 female; $M_{age}$ = 28.22 years, $SD$ = 10.76) were recruited from a participant pool consisting mostly of students and staff members of the University of Cambridge and some volunteers unrelated to the university. Data from five participants were excluded: two participants previously participated in a related study and were therefore familiar with the procedures, two participants reported insight into the hypothesis, and one participant failed to comply with the experimental procedure.

#### 2.1.2. Determining sample size

So far, two studies were published that we could use as guides when determining the sample size for Experiments 1 and 2, given the similarity in research design: Hofmann et al. (2007) and Friese and Hofmann (2009; Study 1). Friese and Hofmann (2009; Study 1) used a sample of 38 participants to obtain a significant interaction effect between implicit attitudes regarding potato chips and trait self-control on potato chips consumption. Furthermore, Hofmann et al. (2007) tested 51 participants to obtain a significant interaction effect between the

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ego-depletion versus control condition and implicit attitudes regarding candies on their consumption. Therefore, we made a pragmatic decision to test between 90 and 110 participants in Experiments 1 and 2: this was the number of participants we could realistically afford to test based on the size of our participant pool, while still ensuring that our experiments contained considerably larger samples than in Hofmann et al. (2007) and Friese and Hofmann (2009; Study 1). One hundred and twenty-six participants initially signed up for Experiment 1, but 16 of them did not show up, thus determining the final sample size of 110. Similarly, 106 participants initially signed up for Experiment 2, but 13 of them did not show up, thus determining the final sample size of 93. We confirm that we analyzed the data only when the data collection was completed; there was no data stopping in between.

### 2.1.3. Materials

*2.1.3.1. Stimuli* Milk chocolate M&Ms (roughly 45 g or 45 candies per bag) were used as stimuli in line with previous research (e.g. Hofmann et al., 2007). The exact weight of each bag of candies was measured prior to the experiment to serve as baseline.

*2.1.3.2. Taste evaluation questionnaire* The questionnaire was adopted from previous work (e.g. Hofmann, Gschwendner et al., 2008) and consisted of eighteen items, of which fourteen items were fillers assessing different aspects of the taste of M&Ms (e.g., sweetness; intensity of chocolate flavor), thus making the cover story of a consumer taste test plausible. Three items were used to compute participants' self-reported attitude towards the candies (see Potential confounds: Self-reported attitudes regarding M&Ms), and one item assessed how frequently people usually ate this type of candies (see Potential confounds: Frequency of eating candies).

*2.1.3.3. Awake-tiredness* The extent to which participants were awake versus tired was assessed using the *awake-tiredness* dimension from the scale developed by Schimmack and Grob (2000). For three words describing different states related to being awake (awake, wakeful, alert), and three words related to tiredness (sleepy, tired, drowsy) participants indicated to what extent they were experiencing each of these states at the moment on a scale from "1 = very slightly or not at all" to "5 = extremely". The awake-tiredness scores across participants were then calculated by subtracting the sum for the tiredness-related items from the sum for the awake-related items; higher scores thus indicate being more awake.

*2.1.3.4. Potential confounds: Self-reported attitudes regarding M&Ms; frequency of eating the candies; and gender.* Self-reported attitudes regarding M&Ms were measured via three items ($\alpha = 0.91$) embedded in the taste evaluation questionnaire: (a) Overall, please rate how tasty you find the candies; (b) Overall, please rate how much you like the candies; and (c) How would you describe the candies? Items (a) and (b) were answered on a scale from "1 = not at all" to "5 = very much", and item (c) on a scale from "1 = not delicious" to "5 = very delicious".

Furthermore, participants' frequency of eating M&Ms was measured via one item embedded in the taste evaluation questionnaire: How often do you eat this type of candies (or some similar candies)? The item was answered on a scale from "1 = never eaten it before" to "5 = often eaten it before". Also, given that differences between men and women were previously observed in regard to eating behavior (Kiefer, Rathmanner, & Kunze, 2005), we asked all participants to report their gender (male vs. female) to probe this variable as a potential confound.

### 2.1.4. Procedure

Participants in all experiments were tested individually by a male experimenter (D. K.). They were first asked to sign the informed consent form that also contained a question about their gender. Thereafter, each participant was seated at a white desk (dimensions: length (160 cm) × width (80 cm)) and told that the purpose of the experiment was to investigate visual and gustatory (taste) perception of candies. The first task involved estimating the distance between a card with participants' own name that was placed immediately in front of them (Krpan & Schnall, 2014a; Markman & Brendl, 2005) and the front edge of a plastic bowl (diameter = 10 cm). For the first five trials, which were introduced to participants as practice trials, the bowl was empty, whereas in the latter five trials the bowl was filled with M&Ms from the pre-weighted bags. When the experimenter first showed the candies to participants, he made it clear that these were the candies they would later taste. Both the empty bowl and the bowl with candies were presented at predetermined distance positions (25 cm, 35 cm, 45 cm, 50 cm, and 55 cm), one at a time.[4] The experimenter adjusted the bowl to correspond to a predetermined location while participants, who had their eyes closed, thought that he was measuring the distance between their name and the bowl. The order of distance positions was counterbalanced across participants.

A perceptual matching task (Krpan & Schnall, 2014a; Linkenauger, Witt, Bakdash, Stefanucci, & Proffitt, 2009; Stefanucci & Geuss, 2009) was used to assess distance estimates. The experimenter stood behind the desk and held a measuring tape that he adjusted to correspond to perceived distance according to participants' instructions by stretching it in a direction parallel to their eyes and the edge of the desk (see Fig. 1). Only the back of the tape (with no measurement units) was visible to them.

Then participants completed the second part of the experiment, which was introduced as the taste evaluation phase. They were given the M&Ms used in the distance estimation task and asked to complete the taste evaluation questionnaire. The candies were positioned on the desk immediately behind the upper edge of the taste evaluation questionnaire (printed in landscape format), roughly 25 cm from the edge of the desk. The experimenter instructed participants that they could eat as many candies as they wished, and that they had 5 min to answer all questions. Then the experimenter left the room and returned once the allotted time was up. Subsequently he collected the evaluation questionnaire and removed the candies and weighted the remaining amount in a different room. All participants then completed the post-experiment questionnaire that assessed *awake-tiredness*.[5] Finally, they were debriefed and probed for suspicion regarding the study objective.

## 2.2. Results

### 2.2.1. Preliminary analyses

*2.2.1.1. Computing distance perception* Given that perceived distance to neutral stimuli is not affected by impulsive forces such as motivation, Krpan and Schnall (2014a) used these stimuli as baseline to compute perceived distance regarding rewarding stimuli, thus reducing error

[4] We aimed for distance positions to be spread across the width of the table while avoiding placing the bowl too close to the edge where the card with participants' names was displayed.

[5] As an exploratory variable, we also measured trait self-control (Tangney, Baumeister, & Boone, 2004). Low trait self-control is usually associated with the dominance of the impulsive behavioral system (Hofmann, Friese, & Strack, 2009). Given that the self-control scale developed by Tangney et al. (2004) measures general self-control rather than self-control associated with eating of candies and other appetitive foods, we did not think it would be useful in informing the main findings of Experiment 1. However, we wanted to explore whether this scale would be correlated with the awake-tiredness dimension that was used as a moderator of the link between perceived distance and candy consumption. The self-control scale was positively related to awake-tiredness ($r = 0.304$, $p = 0.002$), thus suggesting that people who were more tired also reported to have weaker self-control. This finding further strengthens the notion that tiredness was associated with the impulsive system.



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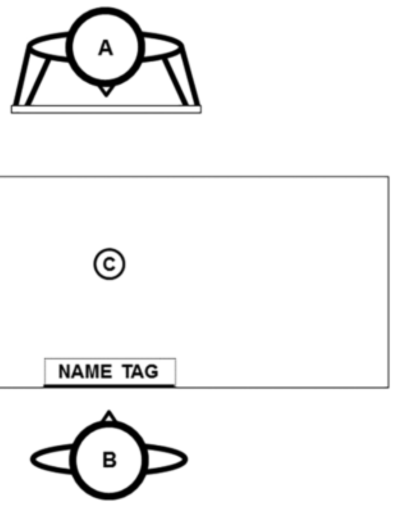


**Fig. 1.** A graphical representation of the distance estimation task in Experiments 1, 2, and 3. Shape A corresponds to the experimenter standing behind the desk and holding a measuring tape parallel to the edge of the desk. Shape B corresponds to a participant seated in front of the name tag. Shape C corresponds to the plastic bowl. Distances were estimated between the front edge of the bowl and the referent line (in bold) printed on the name tag.

variance and enhancing the power to detect the hypothesized effects (Cohen, 1988; Ellis, 1999). Similarly, we used participants' distance estimates to the neutral stimulus (the empty bowl) as a baseline when computing their distance perception regarding the bowl with candies. More precisely, we first divided distance estimates to the bowl with candies by distance estimates to the empty bowl for each of the five predetermined distance positions (25 cm, 35 cm, 45 cm, 50 cm, and 55 cm). Furthermore, we computed an average score across the five distance positions that we used as a measure of perceived distance. Therefore, perceived distance values higher than 1 indicate that the bowl with M&Ms was on average perceived as further away than the empty bowl, whereas values lower than 1 indicate that the candies were perceived as relatively closer.[6] Perceived distance was computed using the same procedure in all three experiments.

*2.2.1.2. Computing candy consumption* Following earlier work (Hofmann & Friese, 2008; Hofmann, Friese, & Roefs, 2009; Hofmann, Gschwendner et al., 2008; Hofmann et al., 2007), participants' candy consumption was computed by subtracting the weight of M&Ms remaining after the taste evaluation task from the baseline weight measured prior to the experiment. Candy consumption was computed using the same procedure in all three experiments.

### *2.2.2. Perceived distance, candy consumption, and awake-tiredness*

To investigate whether perception predicted candy consumption for tired participants, we conducted an analysis of simple slopes (Aiken & West, 1991). More precisely, we computed the interaction between *awake-tiredness* as a continuous moderator and distance estimates as a continuous predictor and inspected the slope of the relationship between perception and eating at low (− 1 *SD*; *tired*) and high (+ 1 *SD*; *awake*) levels of the moderator. The analysis was implemented using the Process package (Model 1) for SPSS (Hayes, 2013). The interaction effect was significant, $b = -14.657$, $p = 0.031$, 95% CI [− 27.931, − 1.382], thus suggesting that the relationship between distance estimates and eating depended on the extent to which participants were awake vs. tired. Indeed, for tired participants, perceived distance and candy consumption were positively related, $b = 104.067$, $p = 0.010$, 95% CI [25.004, 183.131], indicating that participants who saw the candies as further away also ate more (see Fig. 2). In contrast, for awake participants, perception did not predict eating, $b = -26.923$, $p = 0.529$, 95% CI [− 111.394, 57.548]. Therefore, as hypothesized, perception predicted subsequent candy consumption only for tired participants. The main effect of perceived distance, $b = 38.572$, $p = 0.178$, 95% CI [− 17.770, 94.914], was not significant, whereas the main effect of *awake-tiredness* was significant, $b = -0.680$, $p = 0.022$, 95% CI [− 1.261, − 0.099], thus suggesting that participants who were more awake also ate slightly fewer candies.

### *2.2.3. Confound tests*

To demonstrate the robustness of the findings, we repeated the main analysis while also including the frequency of eating M&Ms, self-reported attitudes towards them, and gender as covariates. As before, the relationship between perceived distance and candy consumption was highly significant for tired participants, $b = 112.884$, $p = 0.002$, 95% CI [43.040, 182.727]. Furthermore, for awake participants, perception and candy consumption remained unrelated, $b = 12.391$, $p = 0.746$, 95% CI [− 63.230, 88.012]. In sum, the relationship between perception and eating at different levels of *awake-tiredness* remained in line with our predictions, thus ruling out potential confounds.

## *2.3. Discussion*

Overall, Experiment 1 supported the notion that perception should predict candy consumption only under circumstances that foster the impulsive system (Balcetis, 2016; Hofmann, Friese, & Strack, 2009; Krpan & Schnall, 2014a). As expected, distance estimates regarding candies and the amount consumed were related only for participants who reported to be tired, but not for those who were awake. The direction of this relationship was positive: those who perceived M&Ms as

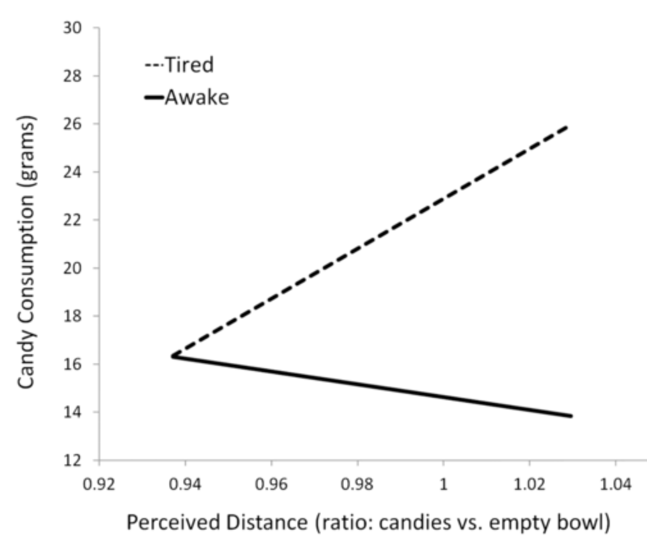


**Fig. 2.** The slope of the relationship between perceived distance to M&Ms, expressed as a ratio of distance estimates to the bowl with candies versus the empty bowl ($M = 0.983$, $SD = 0.046$), and the amount of candies consumed in grams ($M = 17.876$, $SD = 13.874$) for tired versus awake participants (Experiment 1). One candy weighs approximately 1 g.

[6] One could argue that this measure of distance estimates reflects weight rather than distance perception, given that heavier objects (in this case the bowl with candies) are more difficult to act on, and based on Proffitt's (2006) economy of action account may therefore be perceived as more distant. However, if that was indeed the case, then the bowl with candies should consistently be perceived as further away than the empty bowl. This was, however, not the case. In all three experiments, the average perceived distance was below 1, which means that the bowl with candies was actually perceived as closer than the empty bowl (Experiment 1: $M = 0.983$, $SD = 0.046$, Experiment 2: $M = 0.979$, $SD = 0.052$; Experiment 3: $M = 0.987$; $SD = 0.053$). Hence, it is unlikely that perceptual estimates reflected weight rather than distance perception.

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farther also ate more. Therefore, the present findings are in line with research by Krpan and Schnall (2014a), according to which an increase in perceived distance reflects that the person is strongly motivated to consume candies, given that this motivational state reflects congruity with the evolutionary adaptive response to rewarding foods—eating.

Although Experiment 1 provided preliminary evidence in support of the notion that the dual systems account determines the relationship between perception and eating, it also suffered from certain limitations. First, we relied on participants' self-reports, and it is well known that people do not always have insight into their mental and physical states (Nisbett & Wilson, 1977). Second, we assessed participants' degree of tiredness at the end rather than at the beginning of the experiment; self-reported awake-tiredness may have therefore been confounded by their experience of the experimental procedure. Finally, we did not actually demonstrate that awake participants based their decision on processes linked to the reflective system, whereas tired people did not. To address these limitations, we conducted Experiment 2.

## 3. Experiment 2

One aspect that makes the impulsive system more likely to shape behavior is ego-depletion (Baumeister et al., 1998; Schmeichel, Harmon-Jones, & Harmon-Jones, 2010; Strack & Deutsch, 2004). Indeed, engaging in an effortful activity may subsequently decrease a person's capacity to act in line with his/her conscious dietary standards, thus enhancing motivational influences on food consumption (Hofmann et al., 2007; Ostafin, Marlatt, & Greenwald, 2008). In such situations, eating is driven by motivational forces rather than by rational criteria (Hofmann, Friese, & Strack, 2009; Hofmann, Friese et al., 2008; Ostafin et al., 2008; Strack & Deutsch, 2004). Therefore, in Experiment 2, we investigated the link between perception and candy consumption for experimentally depleted participants versus those in a neutral control condition. As in Experiment 1, we hypothesized that perceived distance to candies should predict eating only for depleted participants but not for those in the control condition, given that the latter should rely on the reflective system when eating (Hofmann et al., 2007; Krpan & Schnall, 2014a).

To ascertain that the ego depletion manipulation indeed changed the forces driving eating, we also assessed participants' eating restraint regarding candies. Indeed, given that eating restraint is a reflective determinant of candy consumption (Hofmann et al., 2007), we expected this variable to predict eating only for those in the control condition, but not for ego-depleted participants: Restrained eaters from the control group should consume fewer candies than the unrestrained ones (see Hofmann et al., 2007).

### 3.1. Method

#### 3.1.1. Participants and design

Ninety-three participants (61 female; $M_{age}$ = 20.62 years, $SD$ = 4.13) were recruited as in Experiment 1. Data from four participants were excluded: two participants reported insight into the hypothesis, and two participants failed to comply with the experimental procedure. The design involved Depletion (ego-depletion vs. control) as a between-subjects factor.

#### 3.1.2. Materials

*3.1.2.1. Stimuli* Smarties (roughly 38 g or 32 candies per tube) were used as stimuli because they are similar to M&Ms and are relatively more common in the UK, where the experiment was conducted. Two tubes of Smarties were used per participant. The exact weight of candies was measured prior to the experiment to serve as a baseline.

*3.1.2.2. Ego-depletion manipulation* Because a meta-analysis showed that it is the most effective ego-depletion procedure (Hagger, Wood, Stiff, & Chatzisarantis, 2010), the letter-crossing task (Tice, Baumeister, Shmueli, & Muraven, 2007) was used. For participants in the ego-depletion condition, the task consisted of a control block and a depleting block. In the control block, they were given a text taken from a statistical textbook containing 231 letters ‘e’ and were asked to cross off this letter each time it appeared. In the depleting block, they received a similar text containing 256 letters ‘e’ and were asked to cross off this letter only when the following three rules were met: (a) ‘e’ is not the first letter before or after a vowel (‘a’, ‘e’, ‘i’, ‘o’, ‘u’) contained within the same word; (b) ‘e’ is not the second letter before or after a vowel contained within the same word; (c) ‘e’ is not in a word that contains the letter ‘p’. In contrast, the letter crossing task for participants in the control condition contained only the control block.

*3.1.2.3. Manipulation check* To assess the effectiveness of the ego-depletion manipulation, we adopted the manipulation check from Gailliot and Baumeister (2007). Because for participants in the ego-depletion condition the letter task consisted of two blocks, they were asked to indicate how difficult they found each of the blocks separately on a scale from “1 = not difficult at all” to “7 = very difficult”. In contrast, control participants who completed only one block were asked to indicate how difficult they found it using an identical scale. Finally, participants in both conditions answered how effortful overall they found the letter task on a scale from “1 = not effortful at all” to “7 = very effortful”.

*3.1.2.4. Taste evaluation questionnaire* The same questionnaire as in the earlier experiment was used, with the only difference being that the responses were measured on a 6-point scale rather than a 5-point scale, given that we wanted to increase the range of responses to allow for more sensitive statistical analyses regarding the confound testing.

*3.1.2.5. Eating restraint* Eating restraint regarding Smarties was assessed using the following items on a scale from “1 = disagree strongly” to “7 = agree very strongly” ($\alpha$ = 0.87): (a) I ate fewer Smarties than my urge was telling me to eat; (b) I was tempted to eat more Smarties but I restrained myself; (c) I would have eaten more Smarties if I did not control myself; and (d) When the experimenter first showed me Smarties, I experienced a conflict between desiring to eat them and thinking that I should not eat as many as I desire.

*3.1.2.6. Potential confounds: Self-reported attitudes regarding Smarties; frequency of eating the candies; affect; and gender* Self-reported attitudes regarding Smarties ($\alpha$ = 0.85) and the frequency of eating the candies were assessed as in Experiment 1, but with a 6-point response scale. Furthermore, gender was assessed as in the previous experiment. One participant failed to answer two out of three items capturing attitudes regarding Smarties, so his attitude score could not be calculated and was thus not used in statistical analyses involving this variable.

Because previous research showed that affective states are linked to food consumption and choices (e.g. Gardner, Wansink, Kim, & Park, 2014; Macht, 2008), in Experiment 2 we also assessed affect as a potential confound. Participants indicated how they currently felt on a scale from “1 = very negative” to “7 = very positive”.

#### 3.1.3. Procedure

Participants first completed the consent form and then undertook the distance estimation task as in the previous experiment, with the only difference being that the stimuli were presented at different distance positions (20 cm, 25 cm, 35 cm, 40 cm, and 50 cm). The distance positions were altered to ascertain that the effects across present experiments did not occur only for certain distance values. Thereafter, participants completed the ego-depletion versus control manipulations that were introduced as a concentration task. Half of the participants completed the ego-depletion task and the other half the control task (random assignment was used to allocate participants to ego-depletion

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versus control), and they all subsequently completed the manipulation check. Thereafter, participants undertook the taste evaluation task as in Experiments 1. Furthermore, they completed a post-experiment questionnaire assessing eating restraint regarding Smarties and affect. Finally, participants were debriefed and probed for suspicion regarding the study objective.

### 3.2. Results

#### 3.2.1. Preliminary analyses

*3.2.1.1. Manipulation check* To confirm the success of the ego-depletion manipulation, an independent samples *t*-test first showed that participants in the ego-depletion condition on average found the letter task ($M = 4.841$, $SD = 1.140$) more effortful than participants in the control condition ($M = 3.733$, $SD = 1.405$), $t(87) = 4.08$, $p < 0.001$, $d = 0.86$. Furthermore, a dependent samples *t*-test showed that participants in the depletion condition found the depleting block ($M = 4.727$, $SD = 0.973$) more difficult than the control block ($M = 2.273$, $SD = 0.845$), $t(43) = 19.20$, $p < 0.001$, $d = 2.90$. These findings suggest that the ego-depletion manipulation was successful in inducing ego-depletion.

#### 3.2.2. Main analyses

*3.2.2.1. Perceived distance, ego-depletion, and candy consumption* To investigate whether perception predicted candy consumption under ego-depletion versus control, we conducted an analysis of simple slopes (Aiken & West, 1991; Hayes, 2013) as in Experiment 1. More precisely, we computed the interaction between depletion as a dichotomous moderator and distance estimates as a continuous predictor and inspected the slope of the relationship between perception and eating for participants in the ego-depletion and control conditions (Hayes, 2013). A significant interaction effect between perceived distance and depletion suggested that the relationship between distance estimates and candy consumption depended on whether participants were ego-depleted or not, $b = -162.174$, $p = 0.012$, 95% CI [− 288.175, − 36.173]. For depleted participants, perceived distance and candy consumption were positively related, $b = 131.969$, $p = 0.005$, 95% CI [41.556, 222.381], indicating that those who perceived Smarties as further away also ate more (Fig. 3). In contrast, for participants in the control condition perception was not associated with eating, $b = -30.205$, $p = 0.496$, 95% CI [− 117.965, 57.555]. Therefore, as hypothesized, perception predicted subsequent candy consumption only for depleted participants.

The main effect of depletion was not significant, $b = 3.976$, $p = 0.230$, 95% CI [− 2.556, 10.507], thus showing that this variable did not influence candy consumption. Furthermore, the main effect of perceived distance was also not significant, $b = 49.971$, $p = 0.118$, 95% CI [− 13.013, 112.954].

*3.2.2.2. Eating restraint, ego-depletion, and candy consumption* To investigate whether eating restraint regarding candies predicted eating in the control but not the ego-depletion condition, we again computed a simple slopes analysis (Aiken & West, 1991; Hayes, 2013). Depletion was used as a dichotomous moderator and eating restraint as a continuous predictor. A significant interaction effect between the two variables showed that the relationship between participants' level of restraint regarding candies and their consumption depended on whether they were ego-depleted or not, $b = -5.754$, $p = 0.008$, 95% CI [− 9.941, − 1.568]. For depleted participants, eating restraint and candy consumption were not related, $b = 1.492$, $p = 0.304$, 95% CI [− 1.379, 4.363] (Fig. 3). However, for participants in the control condition, eating restraint was negatively related to eating, $b = -4.262$, $p = 0.007$, 95% CI [− 7.309, − 1.215]: more restrained eaters ate fewer Smarties. Therefore, as hypothesized, eating restraint regarding

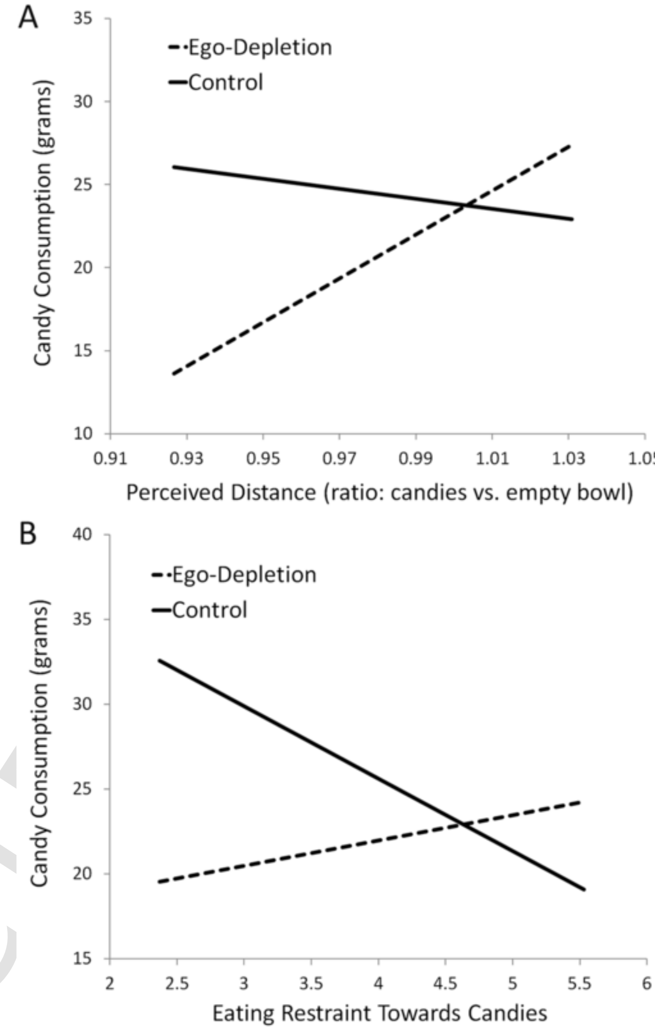


**Fig. 3.** Summary of the findings of Experiment 2. Panel A depicts the slope of the relationship between perceived distance to Smarties, expressed as a ratio of distance estimates to the bowl with candies versus the empty bowl ($M = 0.979$, $SD = 0.052$), and candy consumption in grams ($M = 23.124$, $SD = 15.923$) for participants in the ego-depletion versus control conditions. Furthermore, Panel B represents the slope of the relationship between eating restraint regarding Smarties ($M = 3.949$, $SD = 1.579$) and their consumption for ego-depleted versus control participants. One candy weighs approximately 1.18 g.

candies predicted subsequent eating, but only for participants in the control condition.[7]

The main effect of depletion was not significant, $b = 3.927$, $p = 0.237$, 95% CI [− 2.635, 10.489], thus showing that this variable did not influence candy consumption. Furthermore, the main effect of eating restraint was also not significant, $b = -1.417$, $p = 0.182$, 95% CI [− 3.512, 0.677].

#### 3.2.3. Confound tests

*3.2.3.1. Perceived distance, ego-depletion, and candy consumption* To demonstrate the robustness of the main findings, we computed the slope of the relationship between perception and candy consumption for participants in the-ego depletion and control conditions as in the

[7] Participants in the ego-depletion ($M = 3.681$, $SD = 1.621$) versus control condition ($M = 4.211$, $SD = 1.509$) did not differ regarding eating restraint, $t(87) = -1.60$, $p = 0.114$, $d = 0.34$, thus justifying the use of the depletion variable as a moderator of the link between eating restraint and candy consumption.

main analysis while controlling for self-reported attitudes regarding Smarties, affect, gender, and the frequency of eating the candies. This relationship indeed remained significant for ego-depleted participants, $b = 128.791$, $p = 0.004$, 95% CI [41.427, 216.155], thus showing no confounding effects. As before, no significance was reached for control participants, $b = -17.344$, $p = 0.689$, 95% CI [− 102.942, 68.254].

*3.2.3.2. Eating restraint, ego-depletion, and candy consumption* We conducted the same confound test for eating restraint, to ascertain that the relationship between this variable and candy consumption in the control condition was not confounded by self-reported attitudes regarding Smarties, affect, gender, and the frequency of eating candies. This relationship indeed remained significant, $b = -5.171$, $p = 0.001$, 95% CI [− 8.100, − 2.242], thus showing no confounding effects. Furthermore, the relationship between eating restraint and candy consumption for ego-depleted participants remained insignificant, $b = 0.378$, $p = 0.785$, 95% CI [− 2.371, 3.128].

### 3.3. Discussion

Overall, Experiment 2 substantiated our hypothesis that perception should predict eating of candies under circumstances that foster the impulsive system (Hofmann, Friese, & Strack, 2009; Hofmann, Friese et al., 2008; Krpan & Schnall, 2014a). Indeed, distance estimates predicted candy consumption only for ego-depleted participants but not for those in the control condition. As in Experiment 1, the direction of the relationship was positive: those who perceived the candies as further away also ate more. Therefore, the present findings were again in line with the assumptions by Krpan and Schnall (2014a), according to which seeing appetitive stimuli as more distant reflects the fit between the automatic tendency to consume them and the strong motivation to undertake this action. To ascertain that eating in the control condition but not in the depletion condition was shaped by reflective processes, the present experiment further demonstrated that eating restraint regarding candies predicted eating only for control participants (Hofmann et al., 2007). Overall, these findings suggest that the ego-depletion manipulation determined the dynamics between perception as an impulsive predictor of candy consumption, and eating restraint as a reflective predictor of this behavior.

One aspect of Experiment 2 that warrants discussion is the fact that we assessed perceived distance before rather than after the depletion manipulation (Tice et al., 2007). A critic may argue this is a limitation, given that eating was not measured under the same circumstances as perception. This design was, however, required because of the main assumptions we tested in the present research. Indeed, we argued that perception reflects impulsive processes, and that these processes should determine eating only for depleted participants (Krpan & Schnall, 2014a; Hofmann, Friese, & Strack, 2009). Hence, our aim was not to probe whether depletion influences perception, and whether perception as a consequence mediates the influence of depletion on behaviour (in fact, ego-depletion itself did not have an impact on eating, as reported), but whether depletion changes the link between baseline perception as an impulsive determinant of behaviour and eating. Therefore, our experimental design is in line with previous studies that tested whether ego-depletion modulates the link between the impulsive system and behaviour, given that in all these studies measures of impulsive processes were administered prior to the depletion manipulation (Hofmann, Friese, & Strack, 2009; Hofmann et al., 2007; Ostafin et al., 2008).

Another point worth addressing is why ego-depletion itself did not exert an influence on the amount of candies eaten. Although some studies showed that ego-depletion may make people more likely to consume appetitive foods (see Hagger et al., 2010), other studies (e.g. Hofmann et al., 2007) did not obtain this effect, similar to the present research. A potential explanation behind the lack of influence is that even if ego-depletion makes the impulsive system dominant over the reflective system, this system does not necessarily lead to overeating compared to the reflective system. Indeed, whereas the impulsive system may guide eating via the strength of people's motivation to engage in this behavior, not all people with a dominant impulsive system may be strongly motivated to eat excessively in a given situation (see Strack & Deutsch, 2004). Furthermore, people whose reflective system is dominant over the impulsive system may not always eat little because they may have legitimate reasons regarding why eating more candies just once may not be harmful, especially if they otherwise eat healthily or exercise. Thus, even if ego-depletion enhances impulsive influences on eating, it does not necessarily always need to lead to an increase in this behavior.

Although the present experiment tested the link between distance estimates and candy consumption directly, it did not demonstrate that distance perception is indeed linked to a motivational variable, which is what our explanation behind the present findings suggests (cf. Krpan & Schnall, 2014a). We conducted the next experiment to address this issue.

## 4. Experiment 3

The main goal of the final experiment was to confirm one of the main assumptions posited in the present manuscript: that perceived distance to candies is linked to subjective motivational states (Balcetis, 2016; Hofmann, Friese, & Strack, 2009; Krpan & Schnall, 2014a; Strack & Deutsch, 2004). Therefore, we measured participants' self-reported motivation to consume Smarties. Furthermore, we aimed to replicate the relationship between distance perception and candy consumption for depleted participants to minimize the possibility that this finding occurred due to chance. In the present experiment we depleted all participants and used a larger sample size than in the depletion condition in Experiment 2. We again expected that seeing Smarties as further away would be associated with increased consumption. Furthermore, we predicted that higher self-reports of motivation would be linked to an increase in perceived distance to candies (see Krpan & Schnall, 2014a) and enhanced eating (see Strack & Deutsch, 2004).[8]

### 4.1. Method

#### 4.1.1. Participants

Seventy-six participants (47 female; $M_{age} = 21.87$ years, $SD = 3.54$) were recruited as in the first two experiments. Data from two participants were excluded: One participant reported insight into the hypothesis, and one participant failed to comply with the study procedure due to a physical disability.

#### 4.1.2. Determining sample size

In Experiment 2, the correlation coefficient regarding the relationship between perceived distance and candy consumption in the ego-depletion condition was $r = 0.432$. A power analysis (Champely et al., 2015; Cohen, 1988) showed that replicating this effect would require a sample of 63 subjects (power = 0.95, $\alpha = 0.05$). Based on this estimation, we decided to test roughly 70 participants. Ninety participants initially signed up for the experiment, but 14 of them did not

[8] In Studies 1–3 we also measured participants' self-reported hunger ("How hungry did you feel right at the beginning of this study?") on a scale from "1 = not hungry at all" to "7 = very hungry" because we originally planned to use this variable as a proxy for motivation. However, the variable yielded inconsistent findings, such that in some studies it was positively correlated with both candy consumption and distance estimates, whereas in others no significant correlations emerged. As a consequence, and because hunger may be a general state of food craving that is not aimed specifically at candies, we decided not to use this variable in the present paper.

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show up, thus determining the final sample size of 76. We confirm that we analyzed the data only when the data collection was completed and there was no data stopping in between.

#### 4.1.3. Materials

*4.1.3.1. Stimuli, taste evaluation questionnaire, and ego-depletion manipulation* Smarties were again used as stimuli as in the previous experiment, and the same taste evaluation questionnaire was adopted. Furthermore, the letter-crossing task (Tice et al., 2007) employed in the ego-depletion condition in Experiment 2 was used to deplete all participants.

*4.1.3.2. Motivation to eat Smarties* Motivation was assessed on a scale from "1 = not motivated at all" to "7 = very motivated" using the following question: How motivated were you to eat the candies when you first saw them?

*4.1.3.3. Potential confounds: Self-reported attitudes regarding Smarties; frequency of eating the candies; affect; and gender* Self-reported attitudes regarding Smarties ($\alpha = 0.89$), the frequency of eating the candies, affect, and gender were assessed as in the previous experiment.

#### 4.1.4. Procedure

After first completing the consent form as in previous experiments, participants undertook the distance estimation task. The task was identical to Experiment 2, but with different distances at which the stimuli were presented (25 cm, 30 cm, 35 cm, 40 cm, and 50 cm). The distance positions were altered to ascertain that the effects across present experiments do not occur only for certain distance values. Subsequently, participants engaged in the depletion task as in Experiment 2 and then completed the taste evaluation task. Thereafter, they answered a post-experiment questionnaire that assessed the motivation to eat Smarties and affect. Finally, they were debriefed and probed for suspicion regarding the study objective.

### 4.2. Results

#### 4.2.1. Perceived distance, motivation, and candy consumption

To probe the relationship between perceived distance, motivation, and candy consumption, we computed correlations between these variables. As predicted, perceived distance was positively related to candy consumption: those who saw the candies as further away ate more, $r = 0.377$, $p = 0.001$ (Fig. 4). Furthermore, in line with our assumption that perceived distance is linked to impulsive determinants of behavior, distance estimates were positively related to the motivation to eat candies, thus suggesting that participants who were more motivated to eat the stimuli perceived them as further away, $r = 0.233$, $p = 0.046$ (Fig. 4). The motivational variable was also positively related to the consumption of Smarties, such that highly motivated people ate more, $r = 0.522$, $p < 0.001$ (Fig. 4).

#### 4.2.2. Confound tests

To ascertain that the relationships between perceived distance, motivation, and candy consumption were not confounded by affect, frequency of eating candies, gender, and self-reported attitudes, we performed partial correlation analyses while controlling for these variables. All relationships reported under the main analyses remained significant. In fact, controlling for potential confounds strengthened the relationship between distance estimates and motivation ($r = 0.262$, $p = 0.028$), and between distance estimates and candy consumption ($r = 0.423$, $p < 0.001$). Furthermore, the correlation between motivation and candy consumption was somewhat lowered although still highly significant ($r = 0.462$, $p < 0.001$). Therefore, no confounding effects were observed.

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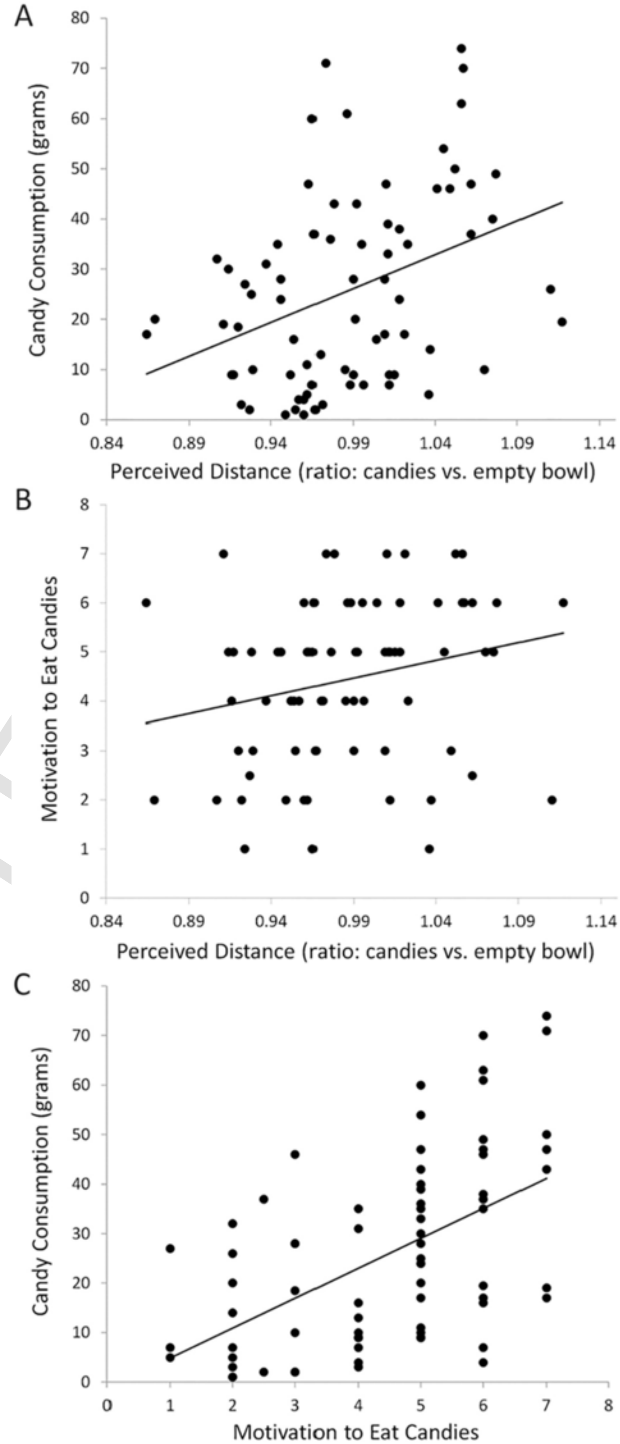


**Fig. 4.** Summary of the findings of Experiment 3. Panel A depicts the correlation between perceived distance to Smarties, expressed as a ratio of distance estimates to the bowl with candies versus the empty bowl ($M = 0.987$, $SD = 0.053$), and the amount of candies consumed in grams ($M = 25.689$, $SD = 19.186$). Panel B represent the correlation between perceived distance to Smarties and the self-reported motivation to consume them ($M = 4.446$, $SD = 1.654$). Panel C corresponds to the correlation between the motivation to consume Smarties and the amount of candies consumed in grams. One candy weighs approximately 1.18 g.

### 4.3. Discussion

Experiment 3 replicated the findings from Experiment 2 by showing that distance estimates were positively correlated with candy consumption for depleted participants: Seeing candies as further away was associated with eating more. Importantly, distance estimates were also positively correlated with the motivation to eat candies. These findings are in line with the notion that perception regarding rewarding stimuli such as candies may be linked to motivational states that fall under the scope of the impulsive system (e.g. Kahneman, 2003, 2011; Krpan & Schnall, 2014a; Strack & Deutsch, 2004).

## 5. General discussion

Across three experiments, the present research tested whether the dual systems account (e.g. Hofmann, Friese, & Strack, 2009) can explain the link between perception and candy consumption. Previous research on spatial perception suggested that perceptual estimates are driven by subjective motivational states rather than by rational thought processes (e.g. Balcetis, 2016; Balcetis & Cole, 2014; Bruner & Goodman, 1947; Balcetis & Dunning, 2010; Krpan & Schnall, 2014a; Proffitt, 2006). Motivation and other intuitive forces referred to as the impulsive system control behavior only when reflective mechanisms such as rational decision making and self-control are impaired (e.g. Evans, 2008; Hofmann, Friese, & Strack, 2009; Kahneman, 2003; Strack & Deutsch, 2004). Therefore, we predicted that visual perception should predict candy consumption only when the impulsive system is dominant in regulating behavior, which is usually the case when people are depleted, tired, or when quick action is required (e.g. Alhola & Polo-Kantola, 2007; Hofmann, Friese, & Strack, 2009; Kahneman, 2003; Strack & Deutsch, 2004).

To test this assumption, in Experiment 1 we explored whether distance estimates predict candy consumption for people who are tired (impulsive system dominance) versus awake (reflective system dominance). The findings revealed that participants who saw M&Ms as further away also ate more, but only if they were tired, thus providing preliminary support for our hypothesis. In Experiment 2, we expanded on this finding by subjecting participants to the ego-depletion (impulsive system dominance) versus control (reflective system dominance) manipulation (see Baumeister et al., 1998; Hofmann, Friese, & Strack, 2009). Besides demonstrating that distance estimates predicted candy consumption only for depleted participants, we showed that eating restraint towards candies—a rational determinant of eating (see Hofmann, Friese, & Strack, 2009)—predicted candy consumption only in the control condition, but not for depleted participants. This finding suggests that the ego-depletion versus control manipulation indeed changed the dominance of forces that determined eating, in line with the dual systems account (Hofmann, Friese, & Strack, 2009; Hofmann et al., 2007). In Experiment 3, we replicated the finding that distance estimates are positively related to eating of candies for ego-depleted participants. Furthermore, we also established that perceived distance was correlated with the self-reported motivation to consume candies, thus providing additional support for our assumption that perception regarding the stimuli is linked to subjective motivational states (see Krpan & Schnall, 2014a). Overall, the present findings demonstrate that the dynamics of perception and action may be determined by the interplay between rational versus motivational processes.

Given that, across all three experiments, seeing the candies as further away predicted eating more, it is necessary to further discuss the direction of this relationship. In the literature regarding motivational influences on perception, there are two inconsistent explanations. According to Balcetis (2016), enhanced motivation to obtain objects in everyday surroundings should make these objects seem closer, given that proximity may have an energizing effect on behavior towards them. However, according to Krpan and Schnall (2014a), motivation to acquire rewarding stimuli should make them appear as further away because this motivational state is compatible with people's natural response to approach rewards. Because the present findings demonstrated the positive association between distance estimates, eating, and self-reported motivation to consume candies, they support the notion proposed by Krpan and Schnall (2014a). However, it is important to point out that the main goal of the present research was not to provide an in-depth investigation of the direction of the relationship between perception and behavior—this is beyond the scope of the present manuscript and will need to be tackled by future research.

Indeed, the goal of the present research was to introduce the dual systems account to the domain of research that investigates how physiological and psychological factors shape perception. Although researchers within this domain have been widely speculating on how perception may be linked to action (e.g. Balcetis, 2016; Krpan & Schnall, 2014a, 2014b; Proffitt, 2006; Witt & Proffitt, 2008), surprisingly few findings have actually demonstrated that visual estimates of size and distance are linked to everyday actions. The present findings suggest that one reason for this may have been the failure to acknowledge that behavior is not shaped only by impulsive forces linked to perception, but also by reasoning and rational thinking (Hofmann, Friese, & Strack, 2009; Kahneman, 2003; Strack & Deutsch, 2004). Therefore, we hope that the present article will prompt other perception researchers to consider the dual systems account when designing their research and will thus spawn new interesting findings regarding perception and action.

Although the present research provided significant advancements to understanding of motivation, perception, and behavior, it also suffers from certain limitations. Therefore, to understand the value of the current findings, it is also essential to understand their constraints.

### 5.1. Limitations

#### 5.1.1. Perception or demand characteristics?

Despite the abundance of findings regarding psychological influences on distance and size perception established by previous research (see Proffitt & Linkenauger, 2013; Schnall, in press-a), critics have argued that the results can be explained by non-perceptual processes such as demand characteristics (Durgin et al., 2009; Durgin, DeWald, Lechich, Li, & Ontiveros, 2011; Durgin, Klein, Spiegel, Strawser, & Williams, 2012; Firestone, 2013; Firestone & Scholl, 2014; Orne, 1962). For example, Firestone and Scholl (2014) argued that the effect of holding a wooden rod across one's chest on the perception of aperture width originally demonstrated by Stefanucci and Geuss (2009) can be accounted for by participants' knowledge of the hypothesis. For a similar reason, Durgin et al. (2009; see also Durgin et al., 2012) criticized the well-established findings regarding the effect of wearing a heavy backpack on hill slant perception (e.g. Bhalla & Proffitt, 1999; Schnall et al., 2010).

However, it is implausible that demand characteristics provide an explanation behind the perceptual effects obtained in the present research (see also Schnall, in press-a, in press-b). First, at the core of our findings are interactions between distance perception and variables such as ego-depletion or tiredness that determined the link between perception and candy consumption. It is highly unlikely that participants had any understanding of the hypothesized processes such that they could have predicted the complex pattern of results obtained in the present research. Indeed, due to our cover story, participants were generally not aware that we were measuring the amount of candies they would eat during the taste testing; the few who did suspect that this was the case were excluded from analyses. Hence, although Firestone and Scholl (2014) and Durgin et al. (2009) speculated that

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demand characteristics can explain psychological influences on distance estimates, this explanation almost certainly cannot apply to the present findings.

### 5.1.2. Ego-depletion

In the present research we employed the ego depletion paradigm (Baumeister et al., 1998; Tice et al., 2007) to manipulate the degree of activation of the reflective versus impulsive system. Although this paradigm has been successfully implemented by numerous researchers (Hagger et al., 2010; Hofmann, Friese, & Strack, 2009), it has recently been subjected to criticisms, primarily because of the failure to replicate specific ego-depletion effects (e.g. Hagger et al., 2016; Lurquin et al., 2016). We believe, however, that these criticisms do not change the validity of the present findings. Indeed, the failed replications primarily focused on investigating the impact of ego-depletion manipulations on computerized tasks such as the operation span task (OSPAN; Lurquin et al., 2016; Turner & Engle, 1989) that measures working memory, and the modified multi-source interference task (MSIT; Bush, Shin, Holmes, Rosen, & Vogt, 2003; Hagger et al., 2016) that measures response inhibition. However, in the present research, the ego-depletion manipulation was used to switch the relative dominance of the impulsive versus reflective system in the context of food consumption (see Hofmann, Friese, & Strack, 2009). The task was clearly successful in this regard: For control participants, eating was predicted by restraint towards candies as a reflective determinant of eating (e.g. Hofmann et al., 2007), whereas in the depletion condition eating was predicted by distance perception as an impulsive precursor (Krpan & Schnall, 2014a) but not by restraint. Therefore, the present research supports the results of other similar studies (Hofmann, Friese, & Strack, 2009) by showing that depleting participants is an effective way of making them more reliant on impulsive rather than reflective forces when eating.

### 5.1.3. The impulsive system and the reflective system

In the present manuscript, we treat the impulsive system and the reflective system in a rather simplistic way as unified constructs that shape behavior in distinct ways. Such a conceptualization is necessary because it allows researchers to produce clearly testable hypotheses and theoretical models (see Hofmann, Friese, & Strack, 2009; Kahneman, 2003; Strack & Deutsch, 2004). However, human behavior is highly complex because it is driven by a large number of processes linked to cognition, emotion, and motivation, some of which cannot be easily categorized within the impulsive versus reflective system distinction because they share certain characteristics of both systems (Evans, 2008; Stanovich & West, 2000; Strack & Deutsch, 2004). Regardless of this limitation of the dual systems account, the present research employed experimental manipulations that created a clear distinction between situations that propel the impulsive versus reflective influences on behavior and showed that these situations changed the link between perception and candy consumption.

In sum, the present paper unites the research on motivational influences on perception with the dual systems account of behavior to provide new insights into the link between perception and action regarding appetitive stimuli. We hope this will open up a new frontier of future work that will uncover the power of visual perception in predicting behavior in everyday situations.

## References

Aiken, L.S., West, S.G., 1991. Multiple regression: Testing and interpreting interactions. Sage, London, UK.
Alhola, P., Polo-Kantola, P., 2007. Sleep deprivation: Impact on cognitive performance. Neuropsychiatric Disease and Treatment 3, 553–567.
Balcetis, E., 2016. Approach and avoidance as organizing structures for motivated distance perception. Emotion Review 8, 115–128.
Balcetis, E., Cole, Z., 2014. Motivated distance perception serves action regulation. In: Forgas, J.P., Harmon-Jones, E. (Eds.), Motivation and its regulation: The control within (Sydney Symposium of Social Psychology). Psychology Press, New York, NY, pp. 263–279.
Balcetis, E., Dunning, D., 2006. See what you want to see: Motivational influences on visual perception. Journal of Personality and Social Psychology 91, 612–625.
Balcetis, E., Dunning, D., 2010. Wishful seeing: More desired objects are seen as closer. Psychological Science 21, 147–152.
Balcetis, E., Lassiter, G.D. (Eds.), 2010. Social psychology of visual perception. Psychology Press, New York, NY.
Baumeister, R.F., Bratslavsky, E., Muraven, M., Tice, D.M., 1998. Ego depletion: Is the active self a limited resource?. Journal of Personality and Social Psychology 74, 1252–1265.
Berridge, K.C., 2009. 'Liking' and 'wanting' food rewards: Brain substrates and roles in eating disorders. Physiology & Behavior 97, 537–550.
Berridge, K.C., Robinson, T.E., Aldridge, J.W., 2009. Dissecting components of reward: 'liking', 'wanting', and learning. Current Opinion in Pharmacology 9, 65–73.
Bhalla, M., Proffitt, D.R., 1999. Visual–motor recalibration in geographical slant perception. Journal of Experimental Psychology: Human Perception and Performance 25, 1076–1096.
Bruner, J.S., Goodman, C.C., 1947. Value and need as organizing factors in perception. The Journal of Abnormal and Social Psychology 42, 33–44.
Bush, G., Shin, L.M., Holmes, J., Rosen, B.R., Vogt, B.A., 2003. The multi-source interference task: Validation study with fMRI in individual subjects. Molecular Psychiatry 8, 60–70.
Cacioppo, J.T., Priester, J.R., Berntson, G.G., 1993. Rudimentary determinants of attitudes: II. Arm flexion and extension have differential effects on attitudes. Journal of Personality and Social Psychology 65, 5–17.
Champely, S., Ekstrom, C., Dalgaard, P., Gill, J., Wunder, J., De Rosario, H., 2015. Pwr: Basic functions for power analysis (R package version 1.1–3). The R Foundation, Vienna, Austria.
Cohen, J., 1988. Statistical power analysis for the behavioral sciences, 2nd ed. Lawrence Erlbaum Associates, Hillsdale, NJ.
Cole, S., Riccio, M., Balcetis, E., 2014. Focused and fired up: Narrowed attention produces perceived proximity and increases goal-relevant action. Motivation and Emotion 38, 815–822.
Dolan, P., Hallsworth, M., Halpern, D., King, D., Metcalfe, R., Vlaev, I., 2012. Influencing behavior: The mindspace way. Journal of Economic Psychology 33, 264–277.
Durgin, F.H., Baird, J.A., Greenburg, M., Russell, R., Shaughnessy, K., Waymouth, S., 2009. Who is being deceived? The experimental demands of wearing a backpack. Psychonomic Bulletin & Review 16, 964–969.
Durgin, F.H., DeWald, D., Lechich, S., Li, Z., Ontiveros, Z., 2011. Action and motivation: Measuring perception or strategies?. Psychonomic Bulletin & Review 18, 1077–1082.
Durgin, F.H., Klein, B., Spiegel, A., Strawser, C.J., Williams, M., 2012. The social psychology of perception experiments: Hills, backpacks, glucose, and the problem of generalizability. Journal of Experimental Psychology: Human Perception and Performance 38, 1582–1595.
Ellis, M.V., 1999. Repeated measures designs. The Counseling Psychologist 27, 552–578.
Evans, J.S.B., 2008. Dual-processing accounts of reasoning, judgment, and social cognition. Annual Review of Psychology 59, 255–278.
Firestone, C., 2013. How "paternalistic" is spatial perception? Why wearing a heavy backpack doesn't—and couldn't—make hills look steeper. Perspectives on Psychological Science 8, 455–473.
Firestone, C., Scholl, B.J., 2014. "Top-down" effects where none should be found: The El Greco fallacy in perception research. Psychological Science 25, 38–46.
Förster, J., 2003. The influence of approach and avoidance motor actions on food intake. European Journal of Social Psychology 33, 339–350.
Friese, M., Hofmann, W., 2009. Control me or I will control you: Impulses, trait self-control, and the guidance of behavior. Journal of Research in Personality 43, 795–805.
Gailliot, M.T., Baumeister, R.F., 2007. Self-regulation and sexual restraint: Dispositionally and temporarily poor self-regulatory abilities contribute to failures at restraining sexual behavior. Personality and Social Psychology Bulletin 33, 173–186.
Gardner, M.P., Wansink, B., Kim, J., Park, S.B., 2014. Better moods for better eating? How mood influences food choice. Journal of Consumer Psychology 24, 320–335.
Hagger, M.S., Wood, C., Stiff, C., Chatzisarantis, N.L., 2010. Ego depletion and the strength model of self-control: A meta-analysis. Psychological Bulletin 136, 495–525.
Hagger, M.S., Chatzisarantis, N.L., Alberts, H., Anggono, C.O., Batailler, C., Birt, A., Zwienenberg, M., 2016. A multi-lab pre-registered replication of the ego-depletion effect. Perspectives on Psychological Science 11, 546–573.
Hayes, A.F., 2013. Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. Guilford Press, New York, NY.
Hofmann, W., Friese, M., 2008. Impulses got the better of me: Alcohol moderates the influence of implicit attitudes toward food cues on eating behavior. Journal of Abnormal Psychology 117, 420–427.
Hofmann, W., Rauch, W., Gawronski, B., 2007. And deplete us not into temptation: Automatic attitudes, dietary restraint, and self-regulatory resources as determinants of eating behavior. Journal of Experimental Social Psychology 43, 497–504.
Hofmann, W., Friese, M., Wiers, R.W., 2008. Impulsive versus reflective influences on health behavior: A theoretical framework and empirical review. Health Psychology Review 2, 111–137.
Hofmann, W., Gschwendner, T., Friese, M., Wiers, R.W., Schmitt, M., 2008. Working memory capacity and self-regulatory behavior: Toward an individual differences perspective on behavior determination by automatic versus controlled processes. Journal of Personality and Social Psychology 95, 962–977.

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Hofmann, W., Friese, M., Roefs, A., 2009. Three ways to resist temptation: The independent contributions of executive attention, inhibitory control, and affect regulation to the impulse control of eating behavior. Journal of Experimental Social Psychology 45, 431–435.
Hofmann, W., Friese, M., Strack, F., 2009. Impulse and self-control from a dual-systems perspective. Perspectives on Psychological Science 4, 162–176.
Kahneman, D., 2003. A perspective on judgment and choice: Mapping bounded rationality. American Psychologist 58, 697–720.
Kahneman, D., 2011. Thinking, fast and slow. Farrar, Straus and Giroux, New York, NY.
Kelley, A.E., 2004. Ventral striatal control of appetitive motivation: Role in ingestive behavior and reward-related learning. Neuroscience & Biobehavioral Reviews 27, 765–776.
Kenrick, D.T., Shiota, M.N., 2008. Approach and avoidance motivation(s): An evolutionary perspective. In: Elliot, A.J., Elliot, A.J. (Eds.), Handbook of approach and avoidance motivation. Psychology Press, New York, NY, pp. 273–288.
Kiefer, I., Rathmanner, T., Kunze, M., 2005. Eating and dieting differences in men and women. Journal of Men's Health and Gender 2, 194–201.
Krpan, D., Schnall, S., 2014. Too close for comfort: Stimulus valence moderates the influence of motivational orientation on distance perception. Journal of Personality and Social Psychology 107, 978–993.
Krpan, D., Schnall, S., 2014. When perception says "no" to action: Approach cues make steep hills appear even steeper. Journal of Experimental Social Psychology 55, 89–98.
Linkenauger, S.A., Witt, J.K., Bakdash, J.Z., Stefanucci, J.K., Proffitt, D.R., 2009. Asymmetrical body perception: A possible role for neural body representations. Psychological Science 20, 1373–1380.
Lupyan, G., 2015. Cognitive penetrability of perception in the age of prediction: Predictive systems are penetrable systems. Review of Philosophy and Psychology 6, 547–569.
Lurquin, J.H., Michaelson, L.E., Barker, J.E., Gustavson, D.E., Von Bastian, C.C., Carruth, N.P., Miyake, A., 2016. No evidence of the ego-depletion effect across task characteristics and individual differences: A pre-registered study. PloS One 11 (2), e0147770.
Macht, M., 2008. How emotions affect eating: A five-way model. Appetite 50, 1–11.
Markman, A.B., Brendl, C., 2005. Constraining theories of embodied cognition. Psychological Science 16, 6–10.
Marr, D., 1982. Vision: A computational investigation in the human representation of visual information. Freeman, San Francisco.
Marteau, T.M., Hollands, G.J., Fletcher, P.C., 2012. Changing human behavior to prevent disease: The importance of targeting automatic processes. Science 337, 1492–1495.
Mead, N.L., Baumeister, R.F., Gino, F., Schweitzer, M.E., Ariely, D., 2009. Too tired to tell the truth: Self-control resource depletion and dishonesty. Journal of Experimental Social Psychology 45, 594–597.
Metcalfe, J., Mischel, W., 1999. A hot/cool-system analysis of delay of gratification: Dynamics of willpower. Psychological Review 106, 3–19.
Michaels, C.F., Carello, C., 1981. Direct perception. Prentice-Hall, Englewood Cliffs, NJ.
Nisbett, R.E., Wilson, T.D., 1977. Telling more than we can know: Verbal reports on mental processes. Psychological Review 84, 231–259.
Orne, M.T., 1962. On the social psychology of the psychological experiment: With particular reference to demand characteristics and their implications. American Psychologist 17, 776–783.
Ostafin, B.D., Marlatt, G.A., Greenwald, A.G., 2008. Drinking without thinking: An implicit measure of alcohol motivation predicts failure to control alcohol use. Behaviour Research and Therapy 46, 1210–1219.
Proffitt, D.R., 2006. Embodied perception and the economy of action. Perspectives on Psychological Science 1, 110–122.
Proffitt, D.R., 2013. An embodied approach to perception by what units are visual perceptions scaled?. Perspectives on Psychological Science 8, 474–483.
Proffitt, D.R., Linkenauger, S.A., 2013. Perception viewed as a phenotypic expression. In: Prinz, W., Beisert, M., Herwig, A. (Eds.), Action science: Foundations of an emerging discipline. MIT Press, Cambridge, MA, pp. 171–198.
Pylyshyn, Z.W., 1999. Is vision continuous with cognition? The case of impenetrability of visual perception. Behavioral and Brain Sciences 22, 341–423.
Pylyshyn, Z.W., 2003. Seeing and visualizing: It's not what you think. MIT Press, Cambridge, MA.
Robbins, T.W., Everitt, B.J., 1996. Neurobehavioural mechanisms of reward and motivation. Current Opinion in Neurobiology 6, 228–236.
Schimmack, U., Grob, A., 2000. Dimensional models of core affect: A quantitative comparison by means of structural equation modelling. European Journal of Personality 14, 325–345.
Schmeichel, B.J., Harmon-Jones, C., Harmon-Jones, E., 2010. Exercising self-control increases approach motivation. Journal of Personality and Social Psychology 99, 162–173.
Schnall, S., Social and contextual constraints on embodied perception. Perspectives on Psychological Science (in press-a).
Schnall, S., No magic bullet in sight: A reply to Firestone and Scholl (2017) and Durgin (2017). Perspectives on Psychological Science (in press-b).
Schnall, S., Zadra, J.R., Proffitt, D.R., 2010. Direct evidence for the economy of action: Glucose and the perception of geographical slant. Perception 39, 464–482.
Stanovich, K.E., West, R.F., 2000. Individual differences in reasoning: Implications for the rationality debate?. Behavioral and Brain Sciences 23, 645–665.
Stefanucci, J.K., Geuss, M.N., 2009. Big people, little world: The body influences size perception. Perception 38, 1782–1795.
Strack, F., Deutsch, R., 2004. Reflective and impulsive determinants of social behavior. Personality and Social Psychology Review 8, 220–247.
Tangney, J.P., Baumeister, R.F., Boone, A.L., 2004. High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. Journal of Personality 72, 271–324.
Tice, D.M., Baumeister, R.F., Shmueli, D., Muraven, M., 2007. Restoring the self: Positive affect helps improve self-regulation following ego depletion. Journal of Experimental Social Psychology 43, 379–384.
Turner, M.L., Engle, R.W., 1989. Is working memory capacity task dependent?. Journal of Memory and Language 28, 127–154.
Vohs, K.D., 2006. Self-regulatory resources power the reflective system: Evidence from five domains. Journal of Consumer Psychology 16, 217–223.
Vohs, K.D., Faber, R.J., 2007. Spent resources: Self-regulatory resource availability affects impulse buying. Journal of Consumer Research 33, 537–547.
Witt, J.K., Proffitt, D.R., 2005. See the ball, hit the ball apparent ball size is correlated with batting average. Psychological Science 16, 937–938.
Witt, J.K., Proffitt, D.R., 2008. Action-specific influences on distance perception: A role for motor simulation. Journal of Experimental Psychology: Human Perception and Performance 34, 1479–1492.
Youngstrom, E., Izard, C.E., 2008. Functions of emotions and emotion-related dysfunction. In: Elliot, A.J., Elliot, A.J. (Eds.), Handbook of approach and avoidance motivation. Psychology Press, New York, NY, pp. 367–384.

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