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The Role of Action Readiness in Motivated Behavior

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According to many theories of motivation and decision making, the principal driver of human behavior is the valuation of actions. Action value is computed as the difference between stimulus value (the benefits and costs inherent in the stimulus that is the target of the action) and action costs (the effort required to perform the action). In the present work, we propose that action costs are crucially influenced by the readiness to perform a given action. We define *action readiness* as the ease with which an action may be initiated given the preaction launch state of the individual. An action that has been frequently or recently performed or rehearsed has a high level of action readiness, whereas an action that has not been frequently or recently performed or rehearsed has a low level of action readiness. By our account, if action readiness levels are high for a given action, decreased action costs may result in action even when the stimulus value is relatively low. Conversely, if action readiness levels are low for a given action, even action costs that appear negligible can dominate positive stimulus values, resulting in seemingly puzzling instances of inaction. We develop and test these ideas in 3 studies across 233 participants using an image-viewing decision context and a logistic prediction model.

Keywords: motivation, decision making, valuation, action readiness, self-control

Why do we do what we do? Theories of motivation and decision making suggest that goal-directed behavior is governed by computations of the value of the potential actions relevant in a given context (Glimcher & Fehr, 2013; Graham & Weiner, 1996). Specifically, we are thought to choose actions that have the greatest subjective action value (Kruglanski et al., 2012; Rangel, Camerer, & Montague, 2008).

The computation of subjective action value involves an integration of the stimulus value and the action costs. Here, the *stimulus value* is defined as the difference between the anticipated benefits derived from the stimulus (that is, the target of the action) and the inherent costs associated with the stimulus. For example, the stimulus value of a snack is the difference between the expected benefit derived from the snack and the price paid. *Action costs* are defined as the costs inherent to performing the action that is being valued. They may involve physical or mental effort (Rangel & Clithero, 2013). For example, the action cost of purchasing a snack may include the effort of walking to a nearby store. The stimulus value and action costs are integrated into action values. This concept has been expressed as follows in the prior literature (Rangel & Hare, 2010):

$$\text{Action Value} = \text{Stimulus Value} - \text{Action Costs}, \qquad (1)$$

where

$$\text{Stimulus Value} = \text{Stimulus Benefits} - \text{Stimulus Costs}. \qquad (2)$$

Theories of motivation and decision making have been understandably concerned with identifying the factors that directly determine the stimulus value and action costs (the variables that, according to Equation 1, determine the value of an action). For example, a substantial body of literature (summarized in Bradley & Lang, 2007) suggests that stimuli that directly or indirectly promote survival (e.g., food, nurturance) often have positive stimulus values, whereas those that threaten an organism often have negative stimulus values. The magnitude of the stimulus value is said to be determined by the intensity of the stimulus (greater intensity produces more positive, or more negative, stimulus values). The magnitude of action costs is similarly thought to be determined by the level of physical or mental effort associated with performing an action (Kool, McGuire, Rosen, & Botvinick, 2010).

The present work is founded on the proposition that stimulus value and action costs are additionally influenced by psychological processes that may not appear to be directly relevant to these variables but are nevertheless crucial in determining their values. In prior work (Suri & Gross, 2015), we have provided empirical evidence supporting the proposition that stimulus value is influenced by the level of endogenous attention directed toward the outcomes associated with that stimulus. In the present work, we

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aim to provide empirical evidence in support of the proposition that action costs are influenced by a person's readiness to perform that action. We define *action readiness* as the ease with which an action may be initiated given the preaction launch state of the individual.

We propose that an action that has been frequently or recently performed or rehearsed has a high level of action readiness, whereas an action that has not been frequently or recently performed or rehearsed has a low level of action readiness. We further hypothesize (but do not test in the present work) that action readiness may also be increased by attending to affordances present in a stimulus that are related to that action (Norman, 1999). *Affordances* are defined as the properties of a stimulus that suggest the possibility of an action (e.g., the handle of a suitcase may suggest lifting it). Additionally, readiness for an action may be increased by watching another person perform that action.

By our account, if action readiness levels for a given action are low, even action costs that appear to be negligible can dominate positive stimulus values, resulting in seemingly puzzling instances of inaction. For example, patients sometimes do not take medications known to result in valued health outcomes (Suri, Sheppes, Schwartz, & Gross, 2013). We attribute this and similar cases (e.g., not taking a few minutes to sign up for beneficial retirement accounts), in part, to a lack of action readiness with respect to the relevant actions in a given context. Conversely, if action readiness levels for a given action are high, decreased action costs may result in action even when the stimulus value is low. For example, people continue to snack well past satiation because the food item remains within easy reach (Cohen & Farley, 2008), as though the act of eating has "momentum" (Mehrabian & Riccioni, 1986). We attribute this and similar cases (e.g., sitting in the same chair on repeat visits to a classroom), in part, to increased action readiness with respect to the relevant actions in a given context.

Constructs potentially related to action readiness have been tested in controlled laboratory environments—although not by manipulating action readiness and not in contexts that have included stimulus values or action costs. For example, previously encountered stimuli (e.g., words, faces, objects) have been shown to elicit increased accuracy and increased speed of response during retrieval compared to stimuli that have not been encountered before (Forster & Davis, 1984). Electrophysiological and fMRI findings suggest that such improvements are driven by "tuning" or "sharpening" of the residual representation of the repeated stimulus (Bargh, 2006; Wagner & Koutstaal, 2002). However, these repetition priming effects were observed in the context of multiple exposures to the same stimulus—and not due to repetition of the same action (which might have increased action readiness). Further, in these studies, participants were not required to make trial-by-trial value judgments—rather, they were required to complete a single action (per trial) that involved perceiving, identifying, and/or categorizing stimuli as quickly as they could. It thus remains unknown whether action readiness influences goal-directed behavior that involves (the putatively more powerful) stimulus valuations.

In the present work, our aim was to determine whether it is possible for action readiness to influence actions when stimulus values are clearly present and action costs are apparently negligible. Concretely, we sought to determine whether a lack of action readiness (with respect to a specific action) could reduce completion rates of that action—even though that action was known to have a positive stimulus value. Further, we sought to test whether holding stimulus values constant, but increasing action readiness (thereby reducing action costs), could increase completion rates of those actions.

To meet these goals, we created a decision context in which study participants had two action options available to them in every trial. Each action option had a clearly defined stimulus value and action costs. In this context, participants frequently failed to take highly valued actions (with a positive stimulus value and apparently negligible action costs) which, according to motivational accounts not including action readiness, they should almost always have completed (Study 1a). We next (Study 1b) created a logistic model to test whether action readiness could explain participant behavior in Study 1a. The logistic model suggested that frequent prior action and recent action increased the subsequent likelihood of the occurrence of that action (supporting the hypothesis that whether or not an action is completed is, in part, dependent on its action readiness). We next tested the predictions and the generalizability of the logistic model using new stimuli and participants (that were not used in developing the logistic model; Study 2). Finally, the logistic model suggested that *mandating* action early in the experiment should increase action readiness levels throughout the experiment—thereby resulting in higher levels of action completion (even though there were no apparent changes to the stimulus value and action costs). We found this to be the case; further, these increased levels of action completion were accurately predicted by the logistic model (Study 3).

Study 1a: Creating a Behavioral Context in Which Action Readiness Effects Are Evident

To investigate the role of action readiness in decision making, we sought to create a context in which stimulus values and action costs were well understood and could be independently manipulated. Further, we sought to measure participants' decisions over a series of trials—this would allow us to determine whether frequent actions and recent actions of a particular type make subsequent action of that type more likely.

One context that seemed promising given our goals was choosing between affective images (Lang, Bradley, & Cuthbert, 1999). According to a standard hedonic account (Higgins, 1998), the stimulus value of a higher valenced (more pleasant or less negative) image is reliably greater than the stimulus value of a lower valenced image.

We measured participant behavior in two separate contexts. In the first context (required choice), we required participants to press one button to view a higher valenced image and another button to view a lower valenced image. In this case, since the action costs for viewing the two images were equal, stimulus values would determine participant behavior. We therefore hypothesized that, barring error or idiosyncratic preferences, participants would always press the button associated with the higher valenced image.

In the second context (proactive choice), participants were presented with a lower valenced image and had the option to proactively press a button to view a higher valenced image. The stimulus value of viewing a higher valenced image was thus pitted against the seemingly negligible cost of a button press. In this context, most theories of motivation and decision making would predict very frequent button presses nearly on par with the required choice context. However, based on our analysis of the role of action readiness, we hypothesized that participants—who had low levels of action readiness for completing this action—would choose to switch images much less frequently than they did in the required choice context.

Method

In Study 1a, participants were randomly assigned to one of two groups: the required choice group or the proactive choice group. The purpose of the required choice group was to determine participant preferences in a decision context in which only stimulus values (but not action costs) were relevant. The purpose of the proactive choice group was to determine participant preferences in a context in which both stimulus values and action costs (including the potential effects of action readiness) were relevant.

In the required choice group, in each trial, participants were required to either press *s* to switch away from a lower valenced default image to view a higher valenced image or press *c* to continue viewing a default image. In this context, all participants were asked to make a choice (i.e., press a button) in every trial. The action costs for both options were equal.

In the proactive choice group, in each trial, participants continued to view the (inferior) default image unless they proactively acted (by pressing the *s* key) to switch away from the default image to view a higher valenced image. In this context, participants had the option to act or to do nothing. No action costs were incurred if a participant elected to continue viewing the default image; the physical or mental effort associated with a button press was the action cost associated with viewing the higher valenced image.

To maximize the effect of stimulus valuations, every effort was made to make the positive and negative stimuli as differentiated from neutral stimuli as possible. For negative stimuli, we chose International Affective Picture System (IAPS) images depicting intensely negative scenes (normative valence rating of 3.53, where 1 = *very unpleasant* and 9 = *highly pleasant*) that are reliably known to elicit avoidance behavior (Lang & Bradley, 2010). For positive stimuli, we chose erotic images of the type reliably known to elicit approach behavior among heterosexual males (Knutson, Wimmer, Kuhnen, & Winkielman, 2008).

Eighty participants were randomly assigned to either the proactive choice condition (50 participants) or the required choice condition (30 participants). All participants were heterosexual males between the ages of 18 and 50 who, in preexperiment questionnaires, indicated that they enjoyed viewing erotic images. The sample size in Study 1a and all subsequent studies was based on effect sizes observed in pilot studies.[1] We predetermined sample sizes that would give us adequate power in order to test our hypothesis and stopped data collection when we had obtained this predetermined number of participants.

There were 40 total trials (per participant) with an equal number—20—of two types of trials. The negative-to-neutral trials allowed the selection of a neutral image instead of a default negative image, and the neutral-to-positive trials allowed the selection of a positive image over a default neutral image. Prior to the start of the experiment, all images were sequentially displayed (500 ms/image in random order) so that participants knew the types of images they could expect in the positive, neutral, and negative categories.

In the required choice condition, participants were shown a default image for 1 s. In negative-to-neutral trials, this default image was negatively valenced; in neutral-to-positive trials, this default image was neutrally valenced. After the 1-s initial presentation, participants were presented with a 3-s choice screen (without the image). In negative-to-neutral trials, the choice screen read "Press 's' to switch to a Neutral Image or Press 'c' to view Default Image." In neutral-to-positive trials, the choice screen read "Press 's' to switch to a Positive Image or Press 'c' to view Default Image." The choice screen lasted for 3 s. If no response was recorded, participants were shown the default image; otherwise, the chosen image was displayed for 15 s. Participants were instructed that they were required to make a choice in each trial.

In the proactive choice condition, participants were shown a default image for 1 s. In negative-to-neutral trials, this default image was negatively valenced, and the instruction caption under the initial negative image read "Press 's' to switch to a Neutral Image." In neutral-to-positive trials, this default image was neutrally valenced, and the instruction caption under the initial neutral image read "Press 's' to switch to a Positive Image." Each trial lasted 15 s. If a participant elected not to press *s*, he would see the default image for the entire trial. Otherwise, if a participant elected to press *s* at time *t*, the image would instantly switch, and the participant would view the higher valenced image for $15 - t$ s (see Figure 1).

Every effort was made to ensure that there were no additional hidden stimulus valuations at work. For example, to avoid perceptions of experimenter preferences in favor of or against switching, participants were falsely told that experimenters were equally interested in measuring their autonomic responses to viewing any of the images included in the experiment (no such data were collected). Postexperiment interviews suggested that 100% of participants believed this cover story and acted accordingly. Additionally, we carefully examined the experimental area to remove potential (implicit) triggers that could increase the valuation of action or inaction (Hassin, Aarts, Eitam, Custers, & Kleiman, 2009).

Results and Discussion

Participants in the required choice condition chose to switch the inferior image in 84% of the trials (mean number of switches: 33.5 out of 40, 95% confidence interval [CI] [29.5, 37.5]). Participants in the proactive choice condition chose to switch the inferior image

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[1] Pilot studies and prior work (Suri, Sheppes, Schwartz, & Gross, 2013) suggested that the difference in the rate of switching from the default between the proactive choice and the required choice conditions had a Cohen's *d* greater than 1.2. At a power level of 0.9 and a probability level less than .01, this suggested a cell size of 23 (using a two-tailed hypothesis). We (more than) doubled this cell size in the proactive choice group of Study 1a to be able to test for potential differences between negative-to-neutral and neutral-to-positive trials (as reported in the text, no such differences were observed). The size of Study 2 was chosen to ensure that it was possible to test for switching differences between males and females (no such differences were observed). The cell size in Study 3 was chosen based on a previously observed effect size of 1.0. At a power level of 0.8 and a probability level less than .05, this suggested a cell size of 17 (using a two-tailed hypothesis). We rounded this up to 20 per cell.

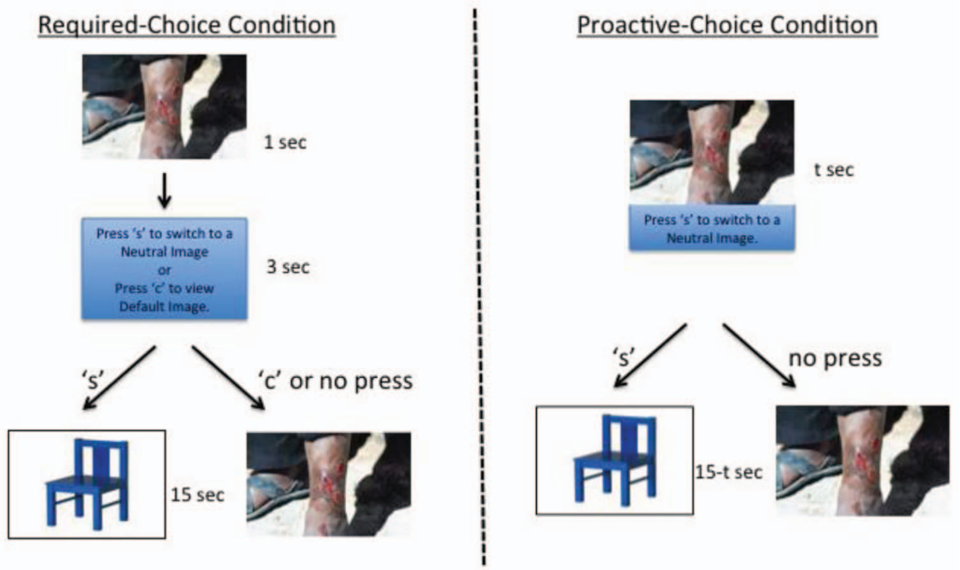

Figure 1. Decision context for the required choice condition (left) and the proactive choice condition (right). See the online article for the color version of this figure.

in 45% of the trials (mean number of switches: 18.0 out of 40, 95% CI [14.9, 21.2]). The difference in the rate of switching from the default between the proactive choice and the required choice conditions is significant, $t(78) = 6.04$, $p < .001$, $d = 1.36$. There was no interaction between condition and trial type (negative-to-neutral vs. neutral-to-positive trials), suggesting that these condition effects generalize across the two different types of trials.

Factors often used to explain inferior outcome preferences (Dinner, Johnson, Goldstein, & Liu, 2011)—implied recommendations and loss aversion—were not applicable in this behavioral context. In postexperiment debriefings, all participants stated that they believed that the purpose of the experiment was to measure their physiological responses upon viewing different images and that the experimenters were indifferent to their viewing choices (thus, implied recommendations were not applicable). Leaving the initially presented image always resulted in superior images (thus, loss aversion was not a factor). Thus, traditional valuation variables did not appear to explain participant behavior in the proactive choice group of Study 1a.

There were two alternative explanations for the seemingly puzzling participant behavior in the proactive choice group. First, it is possible that, negligible as it seems to be, the action cost of the button press was often equal to (or exceeded) the stimulus value of the higher valenced image. Alternatively, it is possible that action readiness for button presses varied throughout the course of the experiment and that, in some cases, the lack of action readiness increased the action cost of button pressing, frequently making it more than the stimulus value of the higher valenced image. We sought to test these two alternatives in Study 1b.

Study 1b: Developing a Logistic Model to Predict Behavior Based on Action Readiness

If the action cost of a button press frequently exceeds the stimulus value of viewing a higher valenced image, then, barring noise, participant behavior on each trial should be independent of behavior in prior trials. Alternatively, if action readiness is influencing participant behavior, then the likelihood of button pressing should be influenced by what the participant did in previous trials. In particular, more frequent and more recent button presses should increase action readiness, thereby decreasing action costs (and increasing action values), with the effect that button presses should be more likely. In Study 1b, we sought to test whether the two hypothesized drivers of action readiness—frequency and recency—could be used to predict participant action and inaction in the proactive choice group of Study 1a (since that was the group in which action readiness effects were hypothesized to be relevant).

Method

We created a model to predict $p(t)$, the probability of a button press at trial t, using two predictor variables—$F(t)$ and $R(t)$. $F(t)$, a frequency variable, measured the *total* number of prior button presses (relative to nonpresses) until trial t. $R(t)$, a recency variable, measured the contribution of recent button presses; that is, those that took place just prior to trial t (see Figure 2). We reasoned that if such a model fit the observed data well, confirmed the statistical significance of both theorized terms [$F(t)$ and $R(t)$], predicted participant behavior well above chance, and made testable predictions that were empirically confirmed, then the case for the influence of action readiness would be strengthened.

$F(t)$ represents participant behavior in all prior trials (prior to t) and is the difference between button presses (1) and nonbutton presses (0) before trial t. For each button press, $F(t)$ was increased by 1, and for a nonpress, it was decreased by 1 (to model that nonpresses created action readiness for nonpresses, not just a lack of readiness for presses). To mark that the first press is especially important with respect to initiating executing readiness, it was given twice the weight (=2) as other button presses (=1; in pilot data, there were twice as many participants with zero button

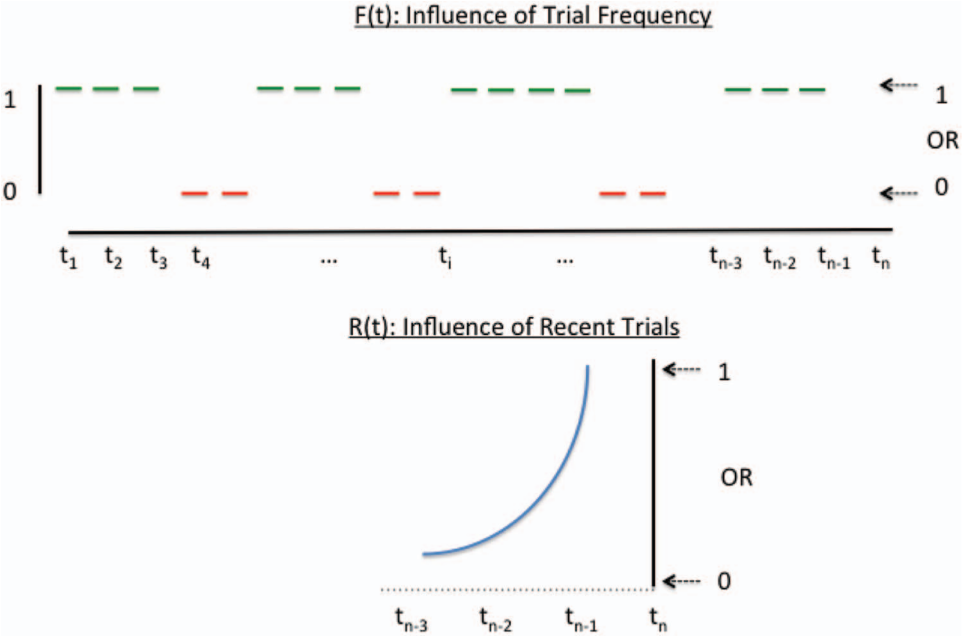

Figure 2. Two factors influence action readiness levels: frequency and recency. The frequency factor measures the influence of actions and inactions in all trials prior to t_n. In this illustrative example, the trials in which an action occurred (top row of dashed lines), outnumber the trials is which the action did not occur (bottom row of dashed lines). The recency factor measures the influence of trials that immediately precede t_n. The influence of the trial immediately preceding t (i.e., t_{n-1}) is the highest; it decays exponentially for prior trials. See the online article for the color version of this figure.

presses than with any other number of presses). Thus, for the first seven trials represented by the string 1110011, $F(8) = 2 + 1 + 1 - 1 - 1 + 1 + 1 = 4$. For the seven trials represented by the string 0000011, $F(8) = -1 - 1 - 1 - 1 - 1 + 2 + 1 = -2$.

$R(t)$ captures the influence of the three immediately prior trials and is equal to $i_{t-1}e^{-1} + i_{t-2}e^{-2} + i_{t-3}e^{-3}$, where i_{t-1}, i_{t-2}, and i_{t-3} are equal to 1 if the $t -$ first, $t -$ second, and $t -$ third trials (respectively) had a button press; otherwise, they equal 0. Here, e represents the natural exponential. For example, if the three trials prior to trial t were all 1s (i.e., button presses), then $R(t) = e^{-1} + e^{-2} + e^{-3}$. On the other hand, if the three trials prior to trial t were all 0s (nonbutton presses), then $R(t) = 0$. The logic behind this formulation of $R(t)$ is that the influence of a button press decays exponentially.

We then used the following logistic regression:

$$\ln[p(t)/(1 - p(t))] = \alpha F(t) + \beta R(t) + e$$

Here, $\ln[p(t)/(1 - p(t))]$ is the logit of the probability (log odds ratio) that a button press occurs at trial t; α and β are model coefficients; and e is the error term.

Results and Discussion

Both $F(t)$ and $R(t)$ were significant in predicting presses or nonpresses (McFadden's $R^2 = 0.26$, representing an excellent fit in the context of a logistic regression; McFadden, 1973). Overall, the model correctly predicted participant choice in 75.1% of trials (well above chance). Models using both $F(t)$ and $R(t)$ were superior to models that used $F(t)$ alone or $R(t)$ alone (deviance $= -6.9$, $p < .01$).

The results of the logistic regression are summarized in Table 1.

The predictive power of the variables in the logistic model suggested two testable predictions related to action readiness. First, the term $R(t)$ implied that participant behavior should be "clumpy"—that is, button presses and nonpresses should tend to occur together. Second, since action readiness patterns shaped in the early trials should cascade to later trials, participant choices in very early trials (i.e., the first two trials) should predict participant behavior in subsequent trials.

To test the clumpiness prediction, we represented a button press in a trial by 1 and a nonpress by 0. The string 11000011111000011100 has more "clumpiness" than 11010010111010010100, though they both have the same number of 1s and 0s.

We used the total number of switches (1 to 0 or 0 to 1) to create a metric c for clumpiness (defined as the total number of switches divided by the total possible switches; lower numbers represent

Table 1
Results of Logistic Regression

	Estimate	Standard error	z value	$Pr(>\lvert z\rvert)$
Intercept	−.26	.08	−3.0	.002
$F(t)$	.10	.006	15.86	$<2 \times 10^{-16}$
$R(t)$	.74	.28	2.64	.008

greater clumpiness). For example, $c(101011)$ is $4/5 = 0.8$ and $c(111100)$ is $1/5 = 0.2$.

To measure the clumpiness of a randomly generated binary string in which the probability of a 1 is 45% (equal to the overall probability of a button press in the proactive choice group of Study 1), we used the bootstrapping method. We randomly generated 10,000 such strings and computed the average clumpiness scores of these strings to be 0.49. The clumpiness score of the Study 1a proactive choice group strings was 0.29—a much higher level than would occur if 1s were randomly distributed ($p < .01$).

To test the early trials prediction, we measured the downstream trial switches of participants who had elected not to switch images in either of the first two trials (00 participants) and compared this to participants who had pressed the button in both of the first two trials (11 participants) and participants who had pressed the button in exactly one of the first two trials (10 or 01 participants). As predicted by the model, the total button presses in the proactive choice group of Study 1 were a function of the action readiness produced in the first two trials; that is, 11 (74%) > 01 (52%) ≈ 10 (51%) > 00 (28%), $F(3, 46) = 9.66$, $p < .01$.

Both the clumpiness and the early trial property provide evidence in support of the hypothesis that action readiness influenced participant behavior in the proactive choice group of Study 1a.

Study 2: Generalizability of Our Logistic Model

We next sought to test the generalizability of the logistic model derived in Study 1b by using stimuli and participants that were different from those used to create the model. This is a necessary step since while Study 1b provided support for the influence of action readiness, it did not prove the general validity of the model derived in Study 1b. To do this, it is necessary to test the predictions of the model in the context of a new data set.

In addition to providing general evidence for the logistic model, we sought to address an important limitation of Study 1a. Specifically, in an attempt to make positive stimuli as motivationally salient as possible, we had limited our stimuli to erotic images and our participants to heterosexual males who acknowledged that they enjoyed viewing erotic images. We had derived our logistic model for this particular demographic and stimulus set. However, we reasoned that since the logistic model was derived purely using action readiness–related features, it should also predict responses for a sample that included males and females and used a different set of stimuli.

Method

Ninety-three participants (58 females) between the ages of 18 and 50 were asked to complete procedures identical to those used for the proactive choice group in Study 1a. However, the stimuli used in Study 2 were different from those used in Study 1a. Unlike in Study 1a, the positive images depicted aesthetically pleasing scenes of nature selected from the Internet (that in preexperimental pilot testing were chosen in 91% of trials over neutral images).

As in Study 1a, participants were (mis)informed that the experimenters wished to measure their affective responses to images and were indifferent to whether they switched or not. A finger pulse monitor was attached to the nondominant hand of each participant. As in previous studies, postexperiment interviews suggested that 100% of participants believed this cover story and acted accordingly.

Results and Discussion

Participants switched images in 42.2% of trials (mean number of switches: 16.9, 95% CI [14.3, 19.4]). This was statistically equivalent to the rate observed in the proactive choice group in Study 1a. The logistic model correctly predicted participant choices in 71.2% of trials (similar to 75.1% for Study 1a participants).

Study 3: Action Initiation or Rehearsal Increases Action Readiness

In Study 3, we tested a crucial implication of our logistic model—namely, that *mandating* action (or action rehearsal) early in the experiment should increase action readiness levels throughout the experiment—thereby resulting in higher levels of proactive action.

Method

In Study 1a (proactive choice group), 38% of the participants had elected not to switch images in either of the first two trials (00 participants). Only 14% of participants had elected to switch in both trials (11 participants). The rest of the participants switched images in exactly one of the first two trials.

Using the logistic model created in Study 1b, we calculated that if all the participants were *required* to switch images in exactly one of the first two trials, then the total number of switches (across all participants, across all trials) would increase to 57% (compared to 45% in Study 1). This would occur because the large number of 00 participants would become 01 or 10 participants. Having an early button press would have cascading effects, resulting in a higher level of button presses.

To calculate the prediction for this higher level, we used the logistic model from Study 1b and assumed that 50% of participants would start with press or no press (10) and that 50% of participants would start with no press or press (01) in the first two trials. We calculated $F(t)$ and $R(t)$ after the first two trials and used these values to calculate the probability of a button press at the next trial (i.e., the first nonmandatory trial). We used the computed probability (say, P for a given trial) and randomly picked a probability, r, from a normal probability curve centered at P. If $r > 50\%$, we assumed a button press; otherwise, we assumed a nonbutton press. We then calculated the button press probability for the next trial until we generated a press/no-press profile for all 40 trials. Using bootstrapping, we calculated that the average number of button presses (after the mandatory trials) should be 57%.

This prediction is at odds with prior motivational and decision-making accounts (that do not feature action readiness) and consistent with accounts featuring action readiness. If only stimulus values and action costs were operational, then required preexperiment trials should not affect action values in later trials.

In Study 3, we selected three levels of action readiness: (a) one-trial practice, which involved physically performing the action required to overcome a default; (b) one-trial rehearsal, which involved mentally rehearsing the action required to overcome a default; and (c) no practice or rehearsal. We hypothesized that physically performing the action would cause greater action readiness (and therefore greater proactive action in switching away from the default) than mental rehearsal, which in turn would cause greater action readiness than no practice.

Sixty participants (selected using the same criteria and stimuli as in Study 1a) were randomly assigned to one of three conditions: physical practice, mental practice, or no practice. Participants in all three conditions were given the proactive choice instructions described in Study 1a. Physical practice participants were asked to complete two additional preexperiment trials. In one—and only one—of these trials, they were required to press the *s* key to switch the default image for another image. In the other trial, they were required to not press the *s* key. The order of these trials was left up to the participants. Mental practice participants were asked to mentally rehearse pressing the *s* key in one (and only one) of two preexperiment trials. They were instructed to imagine—as vividly as possible—their hand coming onto the keyboard and a finger pressing the *s* key. In the other preexperiment trial, participants were asked to imagine—as vividly as possible—their hand staying in its current spot (and not coming to the keyboard and pressing the *s* key). As in the physical practice group, the order of these two trials was left up to the participants. In the no practice condition, participants were allowed to complete the two preexperiment trials in any way they chose (i.e., they were not required to either press or not press *s*).

As in Study 1a, participants were (mis)informed that the experimenters wished to measure their affective responses to images and were indifferent to whether they switched or not. A finger pulse monitor was attached to the nondominant hand of each participant. As in previous studies, postexperiment interviews suggested that 100% of participants believed this cover story and acted accordingly.

Results and Discussion

Participants in the physical practice condition pressed *s* in 62.6% (mean number of switches: 25.1, 95% CI [19.8, 30.2]) of the trials. Participants in the mental practice condition pressed *s* in 52.2% (mean number of switches: 21.1, 95% CI [15.5, 26.7]) of the trials. Participants in the no practice condition pressed *s* in 32.5% (mean number of switches: 12.8, 95% CI [7.7, 18.0]) of the trials (replicating results from the proactive choice group in Study 1a), $t(68) = 1.5$, $p = .12$.

The action costs in each of the groups (i.e., the effort of a button press) apparently appeared to be identical in all groups. Yet, consistent with our account, varying levels of action readiness produced different behaviors.

Both conditions in which action readiness was hypothesized to increase (physical practice and mental practice) produced significantly greater switching than the nonreadiness increasing condition (no practice): physical practice versus no practice: $t(38) = 3.33$, $p = .002$, $d = 1.02$; mental practice versus no practice: $t(38) = 2.19$, $p = .03$, $d = 0.66$. The difference between the physical practice and mental practice conditions was not significant, $t(38) = 1.02$, $p = .31$, suggesting that the action readiness produced by mental rehearsal was not significantly weaker than the action readiness produced by physical action completion.

The value of 57% predicted by the logistic model was within the 95% CI of 50%–76% for the physical practice group. Participants in the no practice group switched images in 33% of all trials—statistically equivalent to the proactive choice group of Study 1a.

General Discussion

We hypothesized that action readiness—the ease with which a new action can be initiated, given the preaction launch state of the individual—influences subjective perceptions of action costs. By our account, holding stimulus valuations constant, a person is more likely to perform a behavior with high levels of action readiness than low levels of action readiness. We further hypothesized that action readiness would increase with the frequency and recency of the performance of that action.

To test these hypotheses, we created a picture-viewing decision context. In Study 1a, participants persisted with an inferior option (a lower valence default image), even though their valuation preference—measured in a forced choice context not involving action readiness factors—was for the nondefault image. In Study 1b, we used a logistic model to show that the prior frequency and recency of an action (here, a button press) predicted the probability of the occurrence of that action. This provided evidence that action readiness drove the observed behavior in Study 1a. In Study 2, we showed that the logistic model predicted behavior for a data set not used to generate the model. Finally, in Study 3, we further confirmed the role of action readiness by examining the effects of requiring participants to act in one of two early trials. As predicted by accounts featuring action readiness, but not by other accounts, the effects of initial actions cascaded throughout the experiment.

We have conceptualized action readiness in terms of increasing or decreasing action costs. Performing an action that has not been frequently or recently performed often requires greater effort than performing actions that have been frequently or recently performed. Such effort may involve cognitive costs (Shenhav, Botvinick, & Cohen, 2013), and these costs may become manifest in several behavioral contexts, including those we have examined in this work.

A second—but we think less apt—way to conceptualize action readiness is in terms of habit. Habit is defined as a preexisting association, strengthened by long-standing repetition, between cue and action (Neal, Wood, & Quinn, 2006). Action readiness, on the other hand, is related to the facilitation of activated action, even when such an action does not result from a long-standing association with a cue. In Study 3, we detected action readiness effects after participants pressed a key just once—which could hardly be labeled a habit. However, we recognize the possibility that action readiness processes may lead to habit formation over time.

Action readiness may provide a new way to analyze behavior in which people persist with an action even though the stimulus value of that action is zero or negative. For example, people have a tendency to repeatedly sit in the same spot in a classroom (even if the seat is not differentiated from other seats; Costa, 2012). Similarly, people continue to snack well past satiation because the food item remains within easy reach (Cohen & Farley, 2008), as though the act of eating has "momentum" (Mehrabian & Riccioni, 1986). By our account, such behaviors occur because the chosen actions (sitting in the same chair or having another bite) have a high level of action readiness. This enables the initiation of actions associated with stimulus values that are zero or negative.

Action readiness may also provide a new way to analyze behavior in which people persist with inaction when seemingly low-cost actions could have resulted in large gains. For example, patients frequently do not take medicines crucial to their health (Suri et al., 2013); employees do not spend a few minutes to start beneficial retirement accounts crucial to their financial future (Beshears, Choi, Laibson, & Madrian, 2006); and individuals do not proactively perform simple actions to obtain their preferred options in decision contexts involving organ donation (Johnson & Goldstein, 2003), electric utilities (Hartman, Doane, & Woo, 1991), and insurance providers (Johnson, Hershey, Meszaros, & Kunreuther, 1993; Samuelson & Zeckhauser, 1988).

Prior analyses have drawn attention to subtle factors that might underlie such behavior, such as implied recommendation and loss aversion (Dinner et al., 2011; Kahneman, Knetsch, & Thaler, 1991). However, these factors do not always appear to apply to these behavioral contexts. By our account, these behaviors occur because they require unfamiliar actions with low action readiness. If such actions had been performed even once before, they would be much more likely to be performed again.

Action readiness may also explain why individuals act inconsistently in what appear to be comparable situations. The valuation calculus described in Equation 1 suggests that if the valuation of a stimulus exceeds associated action costs, then, barring noise, the relevant action should always occur. Similarly, if the valuation of a stimulus is less than the associated action costs, then, barring noise, the relevant action should never occur. The present work suggests the intriguing possibility that seeming inconsistencies in the valuation calculus are not products of random noise but may be attributable to varying levels of readiness to act.

It is possible that action readiness may be an underlying factor in a variety of heuristics and biases. For example, the status quo bias (Samuelson & Zeckhauser, 1988; Suri et al., 2013)—the tendency to prefer the current state—may be driven at least in part by the lack (or presence) of action readiness in a given context. Anchoring and adjustment (Tversky & Kahneman, 1974)—a tendency to continue to disproportionately rely on an initial data point—may result from a lack of action readiness in the processing of new, potentially relevant information. In general, any heuristic or bias that can be attributed to (action) cost avoidance (Shah & Oppenheimer, 2008) may involve action readiness effects.

The effects of action readiness can be observed in a wide array of disciplines. For example, the task switching literature (Rubinstein, Meyer, & Evans, 2001) discriminates between two types of trials: an *n*th trial is a switch trial if it involves a different task from the $n -$ first trial, and it is a repeat trial if it involves the same task as the $n -$ first trial. A large body of evidence has demonstrated that, across various types of tasks, performance on switch trials is worse than on performance trials (Monsell, 2003). While there are several ways to understand this phenomenon, a prominent model suggests that repeated trials are more efficient because of transient carryover of task set "activation" from trial to trial (Gilbert & Shallice, 2002). This activation-based proposal is consistent with the action readiness account described here. Similarly, a propensity for repeating familiar actions may lead individuals and organizations to stay with existing processes and conduct searches (e.g., for new processes) much less than is optimal (Schotter & Braunstein, 1981), even though these new processes may offer significant efficiencies.

Action readiness effects are also abundant in the public policy domain. Many such effects were discussed at length in the influential book *Nudge*, in which Thaler and Sunstein (2008) identified several decisions in which individuals could be nudged to select more optimal options as long as these options were made to be the default options. While several of their examples involved changing the underlying stimulus value, some examples leveraged the role of action readiness in financial- and health-related domains.

Finally, action readiness effects may play an important role in developing effective self-control interventions. Baumeister and Heatherton (1996) propose that the longer a response is repeated, the more difficult it becomes to override. They therefore suggest that self-control attempts are most likely to be successful *before* action readiness increases the costs of stopping an undesirable action. This implies that self-control interventions should ideally target the earliest manifestation of an undesirable behavior and should not be limited to contexts in which a behavior has "hardened" and assumed troubling proportions.

In this study series, we have demonstrated that action readiness effects can be influential even in contexts that include stimulus valuations (Equation 2) that suggest contrary actions. However, action readiness may not always appreciably affect behavior. Many behaviors are largely or entirely shaped by stimulus valuations. Future studies must investigate the circumstances in which action readiness influences behavior to a greater or lesser extent. In one such effort, we recently (Suri & Gross, 2015) found that orienting attention is necessary for stimulus valuations to occur. This suggests the possibility that action readiness effects may be most pronounced when levels of orienting attention are low, as these are the circumstances in which stimulus valuations should play a reduced role.

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