UNDERSTANDING THE ROLE OF CUES IN PREDICTING PHYSICAL ACTIVITY BEHAVIOR

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DEDICATION

I dedicate this to my parents, Andreas and Jackie, for their constant support.

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UNDERSTANDING THE ROLE OF CUES IN PREDICTING PHYSICAL ACTIVITY BEHAVIOR

Cues have been theorized to promote health behaviors but currently our understanding of the effectiveness of cues is inconclusive. The purpose of this systematic review was to assess the effectiveness of cue interventions in promoting physical activity (PA). Six databases were searched which captured 3,996 articles. After comparison with the eligibility criteria, 19 articles were included in the review. Data extraction revealed that while cues were effective in increasing PA behavior, less than half of the studies (n = 8) were supported by theory-based methodologies. We concluded that cue-based interventions are effective for promoting PA behavior, but future research must develop valid measures of cues and incorporate theory into their study designs. The purpose of the thesis study aimed to address this gap by testing if cue consistency would help explain PA habit and behavior through the Dual Process approach. We conducted an observational study with two measurement periods. We recruited 196 participants via an online volunteer registry. Participants completed measures of exercise behavior, intention, habit, perceived behavioral control (PBC), affective attitudes, and cue consistency at baseline and one month later. We ran a Hierarchical Multiple Regression analysis to determine whether a) habit, intention, PBC, affective attitudes, and cue consistency predicted moderate-vigorous physical activity (MVPA) and b) whether PBC, affective attitudes, and cue consistency predicted habit. Our results showed that MVPA was significantly predicted by habit ($\beta = 0.23$, $p < 0.01$), intention ($\beta = 0.16$, $p < 0.05$), PBC ($\beta = 0.23$, $p < 0.01$), affective attitudes ($\beta = 0.20$, $p < 0.05$), and cue consistency (β

= -0.20, $p < 0.05$). Habit was predicted by affective attitudes ($\beta = 0.48$, $p < 0.001$) and cue consistency ($\beta = 0.32$, $p < 0.001$), but PBC ($\beta = 0.10$, $p = 0.11$) was not significant. We found a stronger relationship between cue consistency and habit than previous studies that evaluated cues individually, supporting the cue consistency construct. Our results suggest that cue consistency should be incorporated in the Dual Process approach as a determinant of habit. Future research should look to replicate our findings through cue-based interventions grounded in theory.

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LIST OF ABBREVIATIONS

The following abbreviations appear throughout this paper:

PA- Physical Activity

MVPA- Moderate-to-Vigorous Physical Activity

BCT- Behavior Change Taxonomy

HBM- Health Belief Model

EPHPP- Effective Public Healthcare Practice Project

PBC- Perceived Behavioral Control

Chapter One: Systematic Review of Literature

It is well established that adhering to recommended physical activity (PA) levels (150 mins of moderate-to-vigorous intensity, or 75 mins of vigorous-intensity) can provide several health benefits (Riebe et al., 2018). The health benefits of PA have been observed for chronic disease prevention and treatment (Anderson & Durstine, 2019; Booth et al., 2012; Warburton et al., 2006), reduction of mortality among older adults (Cunningham et al., 2020), and mental health benefits such as reduced symptoms of depression, anxiety, and chronic stress while improving mood and cognition (Hertzog et al., 2008; McEwen, 2007; Penedo & Dahn, 2005). However, only 24% of American adults meet the recommended guidelines (Hyde et al., 2021), which necessitates the need to find effective approaches to promote PA in the general population.

Given the complexity of adopting and maintaining PA, interventions that aim to promote PA would be informative if they were supported by a theory-based design. Specifically, as compared to non-theoretically based approaches, investigations that are framed using theory-based methodology yield more precise findings, keep the literature organized, and can provide formative notes for future interventions or knowledge translational messages (Davis et al., 2015; Hagger et al., 2020; Swanson & Chermack, 2013). The majority of applied theories, such as the Theory of Planned Behavior (Ajzen, 1991) or Social Cognitive Theory (Bandura, 1986), are largely comprised of conscious reasoning constructs. While research using these frameworks have helped identify pertinent determinants for performing exercise behaviors, the findings subsequently revealed limitations of these models, such as the intention behavior gap (Rhodes & Bruijn, 2013). Among several hypotheses put forward to explain diminishing returns of conscious intentions translating to behavior, a theoretical framework that has gained traction and support is Dual Process theory (Evans, 2008). Dual Process theorizing proposes that our behaviors are a contribution of conscious and automatic processes. In the context of exercise, the automatic process towards a behavior is reflected by the strength of the habit. Habit represents the automaticity of a behavior that is guided by contextual factors, such as cues (Lally et al., 2011; Wood & Rünger, 2016). Cues are defined as environmental stimuli that trigger a mental representation of the behavior (Wood & Rünger, 2016) and are a recognized determinant of habit formation.

One of the first health behavior theories to formally acknowledge cues was the Health Belief Model (HBM) (Rosenstock, 1974). The HBM proposes that the engagement in health behaviors is predicted by the push and pull between positive and negative forces perceived by the individual. *Cues to action* were theorized to directly predict the enactment of a health behavior, independent of other perceptions and beliefs. Cues have received support in the literature and have been included in the Behavior Change Taxonomy (BCT) (Michie et al., 2013). Specifically, the BCT proposes that cues can be implemented in an intervention by using one of three approaches (Michie et al., 2013): (a) avoidance/changing the exposure to cues- avoiding exposure to social, contextual, and physical cues that have a negative outcome (Dixon & Johnston, 2010; Michie et al., 2013); (b) prompt cues- a stimulus (such as a phone call, SMS message, or postal reminder) that elicits a specific behavior (such as physical activity or alcohol consumption) (Dixon & Johnston, 2010); (c) discriminative learned cues- an environmental stimulus that has been repeatedly paired with a particular behavior (Dixon & Johnston, 2010). At least in the context of employing the HBM, cues are often excluded from studies (Carpenter, 2010; Jones et al., 2014). Beyond reviews that have supported the theoretical validity of the HBM, there are no systematic reviews that have evaluated the effectiveness of implementing cues for promoting PA/exercise behaviors, independent of the presence/absence of a theoretical model. The purpose of this study was to conduct a systematic review using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to assess if PA interventions that primarily employed cues are effective in promoting behavior change. Specifically, the objectives of this review included comparing the effectiveness of different types of cue interventions, and the length of time needed for cues to demonstrate successful behavior change.

Methods

This systematic review was conducted in accordance with the PRISMA guidelines (Page et al., 2021). All screening, data extraction, and bias assessments were performed using Covidence (*Covidence Systematic Review Software*, 2022).

Eligibility Criteria

Inclusion. Studies were included if they met all the following criteria: (a) measured PA or exercise at pre and post-test; (b) cues were related to PA initiation as opposed to cueing movement during exercise; (c) cues were manipulated as a purpose of the intervention; (d) if the cue was a text message, then it must be sent by an automated system to mimic the control the participant would have in a natural setting; (e) if implementation intentions were used, then they must follow the format "When situation X arises, then I will perform response Y" to generate a cued response. Action plans that used a cue-to-action format were also included (Hagger & Luszczynska, 2014).

Implementation intentions using the “IF…THEN…” format are hypothesized to engage a non-conscious process that automatically connects an initial cue with an appropriate response (Gollwitzer, 1999; Hagger & Luszczynska, 2014). Limiting inclusion to these formats ensured that only plans using cues were reviewed.

Exclusion. Studies were excluded if they were (a) qualitative; (b) observational; (c) included children since they do not have complete behavioral autonomy; (d) used implementation intentions or action plans in the “when, where, and how” format because a cued-response in a single scenario was not specified (Hagger & Luszczynska, 2014); (e) the cue was paired with an additional behavior change taxonomy intervention (e.g., goal setting) because the results could be contaminated (Michie et al., 2013). Non-peer reviewed articles and grey literature were excluded.

Search Strategy

The most recent search was conducted on April 9, 2022, across six databases: Medline (via PubMed), Embase (via embase.com), PsycINFO (via EBSCO), SPORTDiscus (via EBSCO), Scopus (via scopus.com), and Google Scholar (via googlescholar.com). We retrieved the first 200 results from Google Scholar. The search consisted of terms “physical activity”, “exercise”, “cues”, “prompts”, “intervention” and “implementation intention”. The title, abstract, and key terms of the articles were searched. Studies were limited to human subjects, peer-reviewed, and written in English. The full search strategy can be found in Appendix B.

Study Selection

Screening was completed according to the eligibility criteria. The study selection process is illustrated in the PRISMA flowchart (see Figure 1, Appendix A). Duplicates were automatically removed using Covidence. One reviewer completed title and abstract screening and two reviewers completed the full-text review. Discrepancies were discussed until a consensus was reached.

Data Extraction

Items extracted from studies included the title, author, year, aim of the study, number of participants, participant characteristics, theory application, cue feature, outcome variable, measure, and results from the intervention. The results summarized both descriptive and inferential statistics for changes in PA. One reviewer completed the data extraction, and a second reviewer verified the content. Final results were displayed in table format. Themes were established based on common study features.

Bias Assessment

The Effective Public Health Practice Project (EPHPP) quality assessment tool was employed to determine the risk of bias among the included studies (Thomas et al., 2004). The EPHPP assesses selection bias, study design, confounders, blinding, data collection methods, and withdrawals and dropouts. Each category contains a set of questions and according to the responses given, the study is determined to be “strong”, “moderate”, or “weak” in that factor. The article is then holistically ruled as one of the three ratings depending on the number of “weak” categories where zero is “strong”, one is “moderate”, and two or more is “weak”. The EPHPP was chosen because it has shown to have excellent inter-rater reliability for the final grade (Armijo-Olivo et al., 2012). Two reviewers completed the bias assessment and conflicts between reviewers were discussed and resolved until a consensus was reached.

Results

Study Selection

A total of 8,130 articles were imported for screening and 4,134 were removed as duplicates. The title and abstract were screened for the remaining 3,996 articles of which, 3,675 articles did not meet inclusion criteria. Among included trials, 322 articles were assessed in the full-text review, of which n = 19 met all eligibility criteria and were included in this systematic review. Some studies appear to meet eligibility criteria when they do not. For example, Fournier et. al, 2017 conducted a study that investigated whether sending a text message reminder prior to a scheduled exercise session would encourage habit formation (Fournier et al., 2017). While the intervention was cue-based, the authors did not measure PA before the intervention began so the study was excluded.

Study Characteristics

Characteristics of the studies reviewed can be found in Table 1 and Table 2 of Appendix A. A total of 117,060 participants were included in the 19 eligible articles. Study designs included: eight Randomized Controlled Trials (RCT), four Pilot RCTs, six other intervention designs (e.g., incomplete within-subjects crossover, single arm intervention), and one interrupted time series study. Intervention duration ranged from four weeks to one year. Eight studies included participants who were not meeting PA guidelines (Cheung et al., 2012; Kaushal et al., 2021; Kaushal, Rhodes, Spence, et al., 2017; Müller et al., 2016; Prestwich et al., 2010, 2012; van Blarigan et al., 2022; Wang et al., 2015). Eight studies were found to assess clinical populations (Da Silva et al., 2016; Foccardi et al., 2021; Kaushal et al., 2021; Lemanu et al., 2018; Pandey, 2017; Tabak et al., 2014; van Blarigan et al., 2022; Wooldridge et al., 2019). Other population groups included older adults (Antoine Parker & Ellis, 2016; Müller et al., 2016), and university students (Cotten & Prapavessis, 2016; Prestwich et al., 2009). Ten studies assessed PA behavior (Antoine Parker & Ellis, 2016; Cheung et al., 2012; Cotten & Prapavessis, 2016; Eves & Puig-Ribera, 2019; Foccardi et al., 2021; Knoll et al., 2017; Prestwich et al., 2012; Tabak et al., 2014; van Blarigan et al., 2022; Wang et al., 2015), and eight investigated exercise behavior (Da Silva et al., 2016; Kaushal et al., 2021; Kaushal, Rhodes, Spence, et al., 2017; Lemanu et al., 2018; Müller et al., 2016; Pandey, 2017; Prestwich et al., 2009, 2010), and one study assessed both behaviors (Wooldridge et al., 2019). In most cases, exercise and PA behavior were measured using surveys, wearable devices (accelerometers, pedometers), exercise logs, or a combination of these measures. Seven studies used surveys (Antoine Parker & Ellis, 2016; Cotten & Prapavessis, 2016; Foccardi et al., 2021; Kaushal et al., 2021; Lemanu et al., 2018; Prestwich et al., 2010, 2012), five used a wearable device (Cheung et al., 2012; Knoll et al., 2017; Tabak et al., 2014; van Blarigan et al., 2022; Wang et al., 2015), and one used exercise logs (Pandey, 2017). Two studies used surveys and wearable devices (Kaushal, Rhodes, Spence, et al., 2017; Wooldridge et al., 2019), two studies used logs and surveys (Müller et al., 2016; Prestwich et al., 2009), and one study used logs and accelerometers/pedometers (Da Silva et al., 2016). One study coded pedestrian choices through an observer (Eves & Puig-Ribera, 2019).

Effective Public Healthcare Practice Project (EPHPP). As per the EPHPP evaluation, nine studies were graded as “strong”, five as “moderate” and five “weak” (see Table 2 in Appendix A). Studies that were graded as “weak” commonly used less robust study designs or did not report the design at all. Similarly, “weak” studies commonly used data collection tools that had not been tested for validity and reliability or did not report whether they were validated. Studies that were graded "weak" or "moderate" commonly did not report whether there were confounders or did not control for confounders in the analysis.

Theme 1: Application of Theory

Of the 19 studies reviewed, eight used a theory to guide their intervention (Cheung et al., 2012; Kaushal et al., 2017, 2021; Knoll et al., 2017; Prestwich et al., 2009, 2010, 2012; Wooldridge et al., 2019). Five of the eight studies were interventions that used implementation intentions (Knoll et al., 2017; Prestwich et al., 2009, 2010, 2012; Wooldridge et al., 2019), an application of the Rubicon Model of Action Phases (Hagger & Luszczynska, 2014; Heckhausen & Gollwitzer, 1987). Three studies used implementation intentions alone (Knoll et al., 2017; Prestwich et al., 2012; Wooldridge et al., 2019), two of which found collaborative (plans that include their partner) and regular (plans for themselves) implementation intentions to be effective at increasing PA (Prestwich et al., 2012; Wooldridge et al., 2019). Prestwich (2012) used surveys alone while Wooldridge (2019) used surveys and accelerometers. Both studies found that collaborative implementation intentions were effective at increasing PA for survey data, but for accelerometry data, Wooldridge (2019) did not find any significant results. One study applied the Multi-Process Action Control (M-PAC) approach and found Moderate-Vigorous Physical Activity (MVPA) significantly increased for the intervention compared to the control arm (Kaushal, Rhodes, Spence, et al., 2017). One study used the Dual Process approach to form their intervention and found a large but non-significant effect size for increasing exercise time (Kaushal et al., 2021).

Theme 2: Behavior Change Taxonomy

The BCT describes three distinct cue-based interventions (Michie et al., 2013). The search revealed 14 interventions that qualified as a BCT interventions (Antoine Parker & Ellis, 2016; Cheung et al., 2012; Cotten & Prapavessis, 2016; Da Silva et al., 2016; Eves & Puig-Ribera, 2019; Foccardi et al., 2021; Lemanu et al., 2018; Müller et al., 2016; Pandey, 2017; Prestwich et al., 2009, 2010; Tabak et al., 2014; van Blarigan et al., 2022; Wang et al., 2015), although only two types of cues were found to be implemented in studies including a) prompt cue, and b) discriminative learned cue. The results regarding each theme for these intervention types are described below.

Prompt Cues. The search revealed 13 studies to use prompt cues in their intervention (Antoine Parker & Ellis, 2016; Cheung et al., 2012; Cotten & Prapavessis, 2016; Da Silva et al., 2016; Foccardi et al., 2021; Lemanu et al., 2018; Müller et al., 2016; Pandey, 2017; Prestwich et al., 2009, 2010; Tabak et al., 2014; van Blarigan et al., 2022; Wang et al., 2015). Among these studies, SMS messages were the most common prompt type in eleven studies (Antoine Parker & Ellis, 2016; Cotten & Prapavessis, 2016; Foccardi et al., 2021; Lemanu et al., 2018; Müller et al., 2016; Pandey, 2017; Prestwich et al., 2009, 2010; Tabak et al., 2014; van Blarigan et al., 2022; Wang et al., 2015); two studies used other prompt types (pedometer, vibrating wristband) (Cheung et al., 2012; Da Silva et al., 2016). Nine studies used SMS messages alone (Antoine Parker & Ellis, 2016; Cotten & Prapavessis, 2016; Foccardi et al., 2021; Lemanu et al., 2018; Müller et al., 2016; Pandey, 2017; Tabak et al., 2014; van Blarigan et al., 2022; Wang et al., 2015), and six found that prompting exercise with SMS messages was sufficient to increase PA frequency and minutes compared to a control group (Antoine Parker & Ellis, 2016;

Foccardi et al., 2021; Lemanu et al., 2018; Müller et al., 2016; Pandey et al., 2017; Tabak et al., 2014). One study found that when a participant was not meeting their targeted PA levels, the prompt was effective for increasing their PA minutes compared to participants who were approaching their target activity level (Tabak et al., 2014). Two studies combined SMS messages with implementation intentions, and although both presented mixed findings, the authors agreed that implementation intentions and reminders together are effective for increasing exercise behavior (Prestwich et al., 2009, 2010). One study used a vibrating wristband to prompt exercise, which found that activity levels increased by 11-29% following a prompt (Da Silva et al., 2016). Finally, one study used a pedometer alone as a reminder to be active, which found non-significant increases in PA relative to the control group (Cheung et al., 2012).

Discriminative Learned Cues. One study was classified as a learned cue intervention (Eves & Puig-Ribera, 2019). The researchers conducted three investigations to assess whether the public would learn to associate a specific poster design with the decision to use the stairs instead of escalators. The study included three conditions: a) a baseline period with no poster present; b) *design alone*- the poster design is presented at the point of choice between the stairs and escalator; c) *design + message*- the poster design is presented with a message encouraging stair use. The first investigation confirmed that the baseline and *design alone* conditions were not significantly different at the beginning of the study and that the *design + message* condition significantly increased the likelihood of choosing stair climbing on its own. The second investigation found that after exposure to the *design + message* condition, the *design alone* condition significantly increased the likelihood of choosing the stairs. The final investigation used two locations and compared whether an artistic design or a color alone was sufficient to cue the increased likelihood of choosing the stairs. The results showed that both *design alone* conditions increased the likelihood of choosing the stairs to a similar extent to the *design + message* condition. However, when comparing *design alone* conditions to the baseline, only the color alone condition was found to decrease escalator use. Importantly, the second baseline period for the artistic design condition saw very low escalator use despite there being no intervention present. Eves & Puig-Ribera (2019) concluded that pairing a poster design with a motivational message can increase the likelihood that stairs are used instead of escalators. When the message is removed, and the poster is presented with the design alone, escalator use still decreased as if the message was still there.

Theme 3: Repeated Measurement of Cues

Three studies assessed PA or exercise using repeated measures (Kaushal et al., 2021; Prestwich et al., 2012; Wang et al., 2015). Prestwich et al. (2012) found the effect size for implementation intentions declined over time, although a strong effect was still present at the end of the study. Wang et al. (2015) found a significant increase in PA during the week one which declined back to baseline levels through weeks 2-6. Kaushal et al. (2021) found that the intervention group experienced a small non-significant effect after 3 months and a large non-significant effect size for increasing exercise time at 6 months.

Discussion

Engaging in regular PA relies on several behavioral determinants to successfully adopt and maintain. While several determinants have been supported via reviews and meta-analysis (Carpenter, 2010; Hagger et al., 2018; Hagger & Hamilton, 2021; Teixeira et al., 2012), the effectiveness of cues have not been appraised in a systematic review. The purpose of this study was to evaluate the literature for experimental designs that implemented cues to facilitate PA. The objectives revealed corresponding themes that include the limited application of theory, different types of cues (prompt cues and discriminative learned cues), and that the effectiveness of cues can be time dependent.

Theme 1: Application of Theory

The first theme uncovered an important limitation in the literature which was the scarce use of theory. Implementation intentions were the most commonly applied intervention. Implementation intentions are supposedly based on the Model of Action Phases, although this is not made explicit (Gollwitzer, 1999). Only two studies created a cue-based intervention based on theory. One study demonstrated a medium effect size in behavior change at week 8 (Kaushal et al., 2017), and the other found a large effect size at 6 months, although it was not significant (Kaushal et al., 2021). Unfortunately, no other studies were conducted based on a theoretical design. Applying theory improves the probability of developing a successful intervention because it operates within tested boundaries, provides controlled findings, and can potentially help improve the theory/model (Swanson & Chermack, 2013).

Theme 2: Behavior Change Taxonomy

Assessment of the second theme revealed studies use cues as either prompts or discriminative learned cues from the BCT (Michie et al., 2013). The BCT has a third cue intervention, avoidance/changing exposure to cues, which did not appear in our review. While these interventions were not explicitly excluded, interventions that use cue avoidance or change cue exposure aim to reduce behavior which does not align with the premise of our eligibility criteria. Of the nine studies that used SMS messages alone (Antoine Parker & Ellis, 2016; Cotten & Prapavessis, 2016; Foccardi et al., 2021; Lemanu et al., 2018; Müller et al., 2016; Pandey, 2017; Tabak et al., 2014; van Blarigan et al., 2022; Wang et al., 2015), six resulted in increased PA levels (Antoine Parker & Ellis, 2016; Foccardi et al., 2021; Lemanu et al., 2018; Müller et al., 2016; Pandey, 2017; Tabak et al., 2014). A previous systematic review and meta-analysis found text messaging interventions to yield a small to moderate increase in steps per day (Smith et al., 2020). Although our review employed narrower eligibility criteria to control for confounding variables that could influence PA levels, our findings are congruent with Smith et al. (2020). Investigations that employed prompt cues other than SMS messages were limited to two eligible studies (Cheung et al., 2012; Da Silva et al., 2016). One study found PA levels to increase after the cue was presented (Da Silva et al., 2016). However, the study used a one group cohort design with seven participants who had stroke-related upper limb motor deficit, thus limiting the generalization. Nonetheless, given that nine of thirteen studies yielded significant increases in PA or exercise behavior (Antoine Parker & Ellis, 2016; Da Silva et al., 2016; Foccardi et al., 2021; Lemanu et al., 2018; Müller et al., 2016; Pandey, 2017; Prestwich et al., 2009, 2010; Tabak et al., 2014), we conclude that prompt cues are useful for increasing activity levels.

An interesting finding from a study by Tabak et al. (2014) revealed that the prompt was much more effective at increasing activity levels if the individual was not already on track to reach the target levels of activity. One could infer that the effectiveness of a prompt is partly dependent on the current behavior of the individual, and therefore, already active individuals may not be responsive to prompts. When a prompt is provided, the individual could be deciding whether or not to be active based on their recent behavior. Cues elicit a mental representation of the behavioral response, which is typically acted upon, but a conscious decision to act could be present (Wood & Rünger, 2016). Aligning with this, prompt cues have been found to decrease automaticity, further suggesting a missing theoretical component in the mechanism of prompt cues (Stawarz et al., 2015). Future research will need to establish the mechanisms that are functioning for prompt cues and whether they are distinct from other types of cues. If so, the literature should separate the cues construct into different types of cues and investigate them independently.

The review found one study that applied discriminative learned cues (Eves & Puig-Ribera, 2019). The authors paired a poster design with an encouraging message to increase stair climbing behavior. The design and message were presented for a period of time before all posters were removed. Then, the poster was reintroduced without the message (*design alone*); the hypothesis was that individuals would have paired the poster design with the message and elicit a conditioned response to it by increasing their stair-climbing behavior. As predicted, stair-climbing behavior increased when the design alone was reintroduced. Evidence from Eves and Puig-Ribera (2019) suggests that learned cues can increase activity behavior, but further evidence should be gathered to verify this conclusion.

Theme 3: Repeated Measurement of Cues

The third theme assessed studies that used a repeated measures approach. Three studies were found fit this theme; one study used a prompt intervention (Wang et al., 2015), another used implementation intentions (Prestwich et al., 2012), and the third encouraged participants to form their own cues (Kaushal et al., 2021). Two studies found that the effectiveness of cues decreased over time, although the implementation intention intervention maintained its significance throughout the study period (Prestwich et al., 2012; Wang et al., 2015). The third found the magnitude of the effect increased from month three to month six, although the effect size was not significant (Kaushal et al., 2021). These findings align with prior research which found that the effectiveness of reminders decay over time (Tobias, 2009; Wood & Rünger, 2016). Nonetheless, the evidence supporting this position is still limited and further evidence should be gathered to determine how quickly the effectiveness of prompt cues decays and whether it can be prevented.

Limitations of Included Studies

This systematic review revealed that included studies are methodologically limited by the inconsistent terminology or absence of a definition (the definition of what, cues, theories, interventions). For example, implementation intentions and action planning are used interchangeably despite being distinct interventions (Hagger & Luszczynska, 2014). Therefore, in this review, we included both terms in the search strategy to ensure all relevant studies were found. Implementation intention interventions had to be assessed especially closely to ensure that included articles used the cue format as opposed to the “where, when, and how” format consistent with action planning. Clearly defined and consistent use of the correct terms would prevent such confusion from occurring and streamline the review process.

The second limitation of included studies was the measurement and congruency between conceptual and operational definitions of cues. Only two included studies measured cues themselves after instructing participants to perform a ritual to establish and prompt their own cues (Kaushal et al., 2017, 2021). Other studies not included in this review have combined cues with consistency to evaluate six types of cues: time, people, activity, routine, location, and mood cues (Pimm et al., 2016). Studies assessing cues to action from the HBM typically follow a similar format, providing some examples of cues and asking the degree to which these are relevant to the participant (Chou & Wister, 2005; Nayak & Patel, 2014). While these are two different approaches, both have their limitations. When example cues are presented those are the only cues assessed, thus omitting other potential cues. Additionally, both approaches assume that participants are aware of the cues that influence their behavior. Cues can be activated consciously and deliberately. Alternatively, cues can stimulate thoughts of exercise without conscious action, potentially resulting in performing exercise (Wood & Rünger, 2016). Typically, measurement of cues relies on introspection. While deliberate cue usage can be consciously recalled, nonconscious cues are theorized to operate outside of executive control (Wood & Rünger, 2016). Thus, the assumption is that the individual will be able to deduce which environmental stimuli is initiating their behavior.

Strengths and Limitations of the Review Process

In addition to limitations among studies, this review also possesses limitations that are important to consider. First, we excluded articles that were not available in English. Second, we only included articles that measured PA or exercise and therefore excluded any article that only measured habit as its outcome. Since habit is theorized to mediate the relationship between cues and behavior, a number of articles may have been excluded that provide insight into the effectiveness of cues. Third, over half of included articles were scored either moderate or weak in the bias assessment. Thus, the results of this systematic review should be generalized with caution and more methodologically rigorous research should be conducted to verify our findings. Fourth, the review was not registered and a protocol was not created beforehand.

Despite the limitations this review does possess a number of strengths worth noting. First, a wide search of articles was used that encompassed all forms of cue-based interventions. Second, the eligibility criteria included articles that did not explicitly state their use of cues thus revealing that studies often do not use the correct terminology. Third, the results of this review document the state of the literature regarding cues and provide suggestions for future research that would further our understanding of the mechanisms and applications of cues.

Conclusion

The results of this review demonstrated that cues have the potential to be an effective intervention tool for facilitating PA and exercise. However, more robust studies are required to expand the knowledge to identify the extent to which cues are effective. Future studies are warranted that have a low risk of bias, use the correct/consistent terminology, and design their study based on theory. Cues should be clearly operationalized in the theory, and new measures should be created that do not assume that participants are aware of the cues they use. Developments in theory should distinguish between prompt cues and discriminative learned cues, as the evidence suggests that two different systems are present. Finally, our findings suggest that cues lose their potency over time, but additional replications are required to confirm this phenomenon.

Chapter Two: Statement of the Problem

Designing theory-based cue interventions requires established theoretical models illustrating the predictive pathway from cue to behavior change. The HBM initially introduced cues as a predictor of behavior (Rosenstock, 1974), but subsequent theories have removed the construct without explanation (e.g. Protection Motivation Theory (Rogers, 1975), Theory of Planned Behavior (Ajzen, 1991)). Meta-analyses of the HBM reveal that data was rarely collected on cues which prevented a robust conclusion from being drawn on whether cues impact behavior (Carpenter, 2010; Jones et al., 2014). Without the evidence to support the inclusion of cues in theory, the construct was understandably removed.

In Chapter One, we found that prompt cues and discriminative learned cues increased physical activity behavior. Prompt cues are promising as they can be harnessed by the individual to create behavior change (e.g., by setting reminders, leaving workout clothes on their bed). However, a key limitation among the reviewed studies is the scarcity of theory-based investigations. Grounding interventions in a theoretical model is essential, but there are few theories that include cues in their models. The HBM is the most prominent theory to include cues (Rosenstock, 1974), but modern theories that were specifically designed for PA behavior, such as the Integrated Behavior Change (IBC) model (Hagger & Chatzisarantis, 2014), have more predictive power and so are favored in intervention designs. It is useful to know that cues are recognized in the BCT (Michie et al., 2013) as interventions that employ cues contribute to behavior change (e.g., (Antoine Parker & Ellis, 2016; Eves & Puig-Ribera, 2019; Foccardi et al., 2021; Kaushal et al., 2021; Lemanu et al., 2018; Müller et al., 2016; Pandey, 2017; Prestwich et al., 2009, 2010, 2012; Tabak et al., 2014; van Blarigan et al., 2022; Wang et al., 2015). However, tests and application of their usage is limited since cues are largely absent from theories. To advance the literature, cues must be integrated into modern theory.

Early behavior changes theories (e.g., Theory of Planned Behavior (Ajzen, 1991), Theory of Reasoned Action (Fishbein, 1979)) were proposed with the assumption that behavior was consciously produced by the individual. Despite this popular belief, subsequent evaluation consistently found that intention, the primary predictor of behavior, could only explain a small amount of behavior change (Armitage & Conner, 2001; Conner & Norman, 2022). Thus, researchers have moved to integrate automatic processes into their theoretical research in what is now known as the Dual Process approach (Evans, 2008; Rhodes et al., 2019).

The Dual Process approach emphasizes that two parallel psychological processes contribute to driving our behaviors, specifically, a conscious system and non-conscious system (Evans, 2008). In the context of PA, intention and habit represent leading constructs of conscious and non-conscious processes which proximally predict behavior. Habits are described as "automatic responses with specific features" (Wood & Rünger, 2016, p. 292). The essence of habitual behavior is that the behavior is performed without the individual thinking about it beforehand, known as automaticity. Research thus far has shown that habits are strong predictors of behavior and have been incorporated into prominent theories such as the IBC model (Hagger & Chatzisarantis, 2014). Despite the addition of habit for consistency with the Dual Process approach (Kaushal et al., 2022), the IBC model does not include any predictors of habits. Further understanding of the antecedents of habits could lead to better informed development of interventions that produce stronger outcomes.

Investigating cues as a predictor of habit in the Dual Process model is a unique approach that could be the initial step towards integrating cues into modern behavior change theory. To progress, the measurement of cues must be improved upon. In Chapter One, we found that cues are still rarely measured in studies, thus limiting our understanding of whether individuals use cues and how they use them. An important mechanistic feature for cues to be effective is if they are consistent in their activation and pairing with the behavior. The consistency of cues (such as time of day, location, mood, etc.) have only been tested as individual predictors of automaticity. Given that studies have repeatedly found cues to predict automaticity and behavior (e.g. Pimm et al., 2016; Schumacher et al., 2019) and one study found no difference between routine and time cues in habit formation (Keller et al., 2021), it is parsimonious and plausible to suggest that the consistent presence of different cues as a unified construct may be predicting habit and PA behavior. There is no definition of cue consistency in the literature, so we define cue consistency as the recurrence of specific internal or external stimuli that trigger the mental representation of the associated response. Pimm et al. (2016) have measured the consistency of cue presence with a self-report measure that has demonstrated strong efficacy for collecting reliable data on individual cue use (Hagger, 2019). The measure is ideal for assessing cue consistency as a construct since it evaluates common cues, such as time of day or location, on a Likert scale. Currently, there are no studies that assess the construct of cue consistency as a determinant of habits in the Dual Process approach.

The purpose of this study was to investigate whether cue consistency should be unified as a construct and incorporated in the Dual Process approach. First, we aimed to validate the Dual Process approach by testing whether habits and intention predicted MVPA. Next, we tested the cue consistency construct amongst other recognized habit predictors, specifically perceived behavioral control (PBC) and affective attitudes, to evaluate the strength with which it predicts behavior. We hypothesized that (a) habit and intention would be significant predictors of MVPA and (b) that the cue consistency construct would be a stronger predictor of habit than PBC and affective attitudes.

Chapter Three: Methodology

Methods

Study Design

This study was an observational study with two measurement periods. Participants were instructed to complete a survey at baseline (T1) and one month later (T2). All measures were administered at both timepoints.

Participants/Procedure

Participants were adults residing in the United States. Eligibility criteria limited inclusion to those over 18 years of age. We recruited participants using an online volunteer registry that was created as part of the Clinical Translational Science Award (CTSA) program (Harris et al., 2012). Participants were contacted via approved messages. Individuals were encouraged to follow a link to the first Qualtrics survey (*Qualtrics*, 2005), where they were required to sign the consent form if they wished to participate. After consenting, participants completed the online survey. Using the email address the participant provided at the end of the survey, participants were contacted after one month with the follow-up survey. Participants were offered the chance to win one of four $50 gift cards if they responded to at least 90% of questions. Approval for this study (Protocol #: 15435) was obtained from the Indiana University Institutional Review Board.

Measures

Participants received two identical surveys one month apart that consisted of the following measures. A full copy of each measure is provided in Appendix C.

Moderate-to-Vigorous Physical Activity Time. MVPA time was measured using the Godin Leisure-time Exercise Questionnaire (Godin et al., 1986). The questionnaire consisted of four items that asked participants to report their average weekly exercise time over the past two weeks with respect to vigorous and moderate intensities. Participants reported the total number of sessions and the duration of each session for each exercise intensity. MVPA time was calculated by multiplying the number of sessions by minutes per session for each intensity and summing the values. A higher value of MVPA time indicates that the individual engages in more MVPA.

Habit. The preparatory phase of habit was measured using a modified version of the validated Self-Report Behavioral Automaticity Index (SRBAI) (Gardner et al., 2012). The modified version has demonstrated stronger predictive validity for habit (Kaushal, Rhodes, Meldrum, et al., 2017). The preparatory phase of habit with respect to exercise was described to participants as "all of the activities you would regularly perform before each exercise session at home (e.g., putting on workout clothes, setting up your exercise space)". Participants were presented with four items probing whether they prepare to exercise "automatically", "without having to consciously remember", "without thinking", or "without realizing I am doing it". Participants responded on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree" that was coded from 1 to 5 respectively. A habit score was calculated by averaging the scores from each item, resulting in a final score in the range of 1 to 5, with higher scores indicating stronger levels of habit. Internal consistency was found to be 0.91 at T1 and 0.92 at T2.

Intention. Intention was measured using two validated items (Ajzen, 2019). In each item, participants were asked whether they a) intend or b) expect to be regularly physically active. The responses were given on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree" that was coded from 1 to 5 respectively. An intention score was calculated by averaging the scores from each item, resulting in a final score between 1 and 5, with higher scores indicating stronger intentions to be active. Internal consistency was found to be 0.87 at T1 and 0.90 at T2.

Perceived Behavioral Control. PBC was measured using seven items regarding the exercise experience of participants (Ajzen, 2019). Participants were asked if they feel they have "good athletic ability", "considerable skill when it comes to exercising", "the opportunity to exercise over the next month if I really wanted to", "enough free time in my schedule to be regularly active if I was really motivated to exercise", control over whether they can exercise, control over whether they can exercise for 150 minutes per week, and whether exercising for 150 minutes per week is easy for them to do. The responses were given on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree" which was coded from 1 to 5 respectively. A PBC score was calculated by averaging the scores from each item, resulting in a final score between 1 and 5, with higher scores indicating that the individual believes they have more control over whether they can be physically active. Internal consistency was found to be 0.81 at T1 and 0.86 at T2.

Affective Attitude. Affective attitude was measured using the intrinsic motivation section of the Behavioral Regulation in Exercise Questionnaire- 3 (BREQ-3) (Cid et al., 2018). Four items were given to participants regarding their exercise experience. Items questioned whether they exercise because it is fun, they enjoy it, it is pleasurable, or if they get pleasure and satisfaction from exercise. The responses were given on a 5-point Likert scale ranging from “strongly disagree” to “strongly agree” that was coded from 1 to 5 respectively. An average affective attitude score was calculated by averaging the scores for each item, resulting in a final score between 1 and 5, with higher scores indicating the individual finds more enjoyment in exercising. Internal consistency was found to be 0.95 at T1 and 0.96 at T2.

Cue Consistency. Cue consistency describes the recurrence of specific internal or external stimuli that trigger the mental representation of the associated response. We measured cue consistency using a six item measure from Pimm et al. (2016). The responses are preceded by the statement “each time I start to engage in physical activity…”. The items stated a) “It is the same time of day”; b) “I am around the same people”; c) “I do the same type of activity”; d) “I am in the same part of my daily routine”; e) “I am in the same place”; f) “I am in the same mood or feeling state”. Participants rated each of these on a 5-point Likert scale ranging from “strongly disagree” to “strongly agree” that was coded from 1 to 5 respectively. Previously, each item has been analyzed individually as a specific cue type. We averaged the responses from all six items to produce a cue consistency score to be used in the analysis, ranging from 1 to 5. Higher scores indicate that, on average, the cues measured are more consistently present for the individual. Internal consistency was found to be 0.81 at T1 and 0.84 at T2.

Sample Size Calculation

An estimation of the required sample size for the study was calculated using G Power (Faul et al., 2009). The linear multiple regression test was selected from the F-test family. The power value was set to 0.8, and alpha was set to 0.05. A minimum sample size of 77 participants was required to find an effect size of $f^2 = 0.15$.

Analysis

Data was cleaned using SPSS v. 28.0 (IBM Corp., 2021) and analyzed using RStudio (Posit team, 2022). Outliers were removed from the MVPA variables by identifying datapoints that had a Z score of greater than 3.29 or less than -3.29 (Tabachnick & Fidell, 2013). Outliers could not be identified in habit, intention, PBC, affective attitudes, and cue consistency because their data was collected on a five-point Likert scale.

To maximize the number of complete cases in our dataset, we sought to impute missing values. Prior to imputation, we established that missing data was missing completed at random (MCAR) by conducting Little's MCAR test in SPSS (IBM Corp., 2021). A non-significant result would indicate that there was not a consistent pattern in the missing data, and it would be appropriate to proceed with imputing missing data. Missing data was imputed in RStudio using the predictive mean matching method from the *mice* package (Buuren & Groothuis-Oudshoorn, 2011).

For the analysis, Hierarchical Multiple Regression (HMR) was conducted in RStudio (Posit team, 2022) using the linear model function from the *lme4* package (Bates et al., 2015), and the ANOVA function from the *stats* package (R Core Team, 2022). For HMR, a series of models were created with each subsequent models having more predictors than the last. The regression coefficients of each predictor were standardized using the *QuantPsyc* package (Fletcher, 2022). An ANOVA was run to test whether the additional predictors improved the fit of the model. If significance was found, more predictors were added to the model. The change in r^2 was calculated between models to examine whether more of the variance in the outcome could be explained by including the additional predictor (Field, 2009).

Hypothesis One: MVPA Model. To evaluate the hypothesis that intention and habit predicted MVPA, a series of multiple regression models were created. Our survey collected exercise data based on past behavior and psychological data based on the present. Therefore, to align the temporal aspect of the data, we used T2 MVPA as the outcome and T1 predictors. Block one consisted of habit and intention as predictors of MVPA to validate the Dual Process approach. In block two, we added PBC and affective attitude to establish whether the constructs added any further explanation of MVPA behavior. Cue consistency was added in block three to evaluate whether it predicts MVPA.

Hypothesis Two: Habit Model. To evaluate whether cue consistency predicts habit, a second series of multiple regression models were created. We used the data from T1 to align with the MVPA Model. Block one consisted of PBC because it has been established as a predictor of automaticity in previous research (de Bruijn et al., 2014). In block two, we added affective attitudes to test whether affective attitudes predicted habit in addition to PBC. Cue consistency was added in block three to establish whether cues predicted habit alongside PBC and affective attitudes.

Chapter Four: Results

Participants

Participants (n = 196) were over 18 years of age. Of the original sample, 108 participants (55.1%) completed survey two. One participant withdrew after completing survey one as they misunderstood some of the questions. Three other participants were removed from final analyses as their data could not be matched between surveys. Of the 196 participants that consented, 192 were included in the analysis. The majority (81.2%) of individuals were female with a mean age of 47.6 (SD = 18.3). Almost half (47.6%) of the sample were married, nearly 90% were white, and 89.6% had at least some university education. Participants had a mean MVPA time of 163.14 (SD = 148.65) at T2. A full description of the demographics and descriptive statistics can be found in Table 3 and Table 4, respectively (see Appendix A).

Given that Little's MCAR test was non-significant ($\chi^2 = 4693.02$, df = 4784, $p = 0.824$), we imputed missing values. Bivariate correlations revealed no evidence of multicollinearity. The full table of bivariate correlations after multiple imputation can be found in Table 5 (see Appendix A).

Hierarchical Multiple Regression

Hypothesis One: MVPA Model

In block one (see Figure 2, Appendix A), habit ($\beta = 0.27$, $p < 0.001$) and intention ($\beta = 0.36$, $p < 0.001$) were found to be significant predictors of MVPA. The model was statistically significant [$F(2, 189) = 41.61$, $p < 0.001$, $r^2 = 0.31$] and 31% of the variance in MVPA could be explained by the predictors.

In the second block (see Figure 3, Appendix A), affective attitudes and PBC were added as predictors of MVPA. Habit ($\beta = 0.16$, $p < 0.05$), intention $\beta = 0.18$, $p < 0.05$), affective attitudes ($\beta = 0.21$, $p < 0.05$), and PBC ($\beta = 0.22$, $p < 0.01$) were all significant predictors of MVPA. The model was statistically significant [F(4, 187) = 27.59, $p < 0.001$, $r^2 = 0.37$]. The change in R-squared was 0.06. The ANOVA test between model one and model two was statistically significant ($p < 0.001$) indicating that the additional predictors improved model fit.

The third block (see Figure 4, Appendix A) included cue consistency as a predictor of MVPA. Habit ($\beta = 0.23$, $p < 0.01$), intention ($\beta = 0.16$, $p < 0.05$), PBC ($\beta = 0.23$, $p < 0.01$), affective attitudes ($\beta = 0.20$, $p < 0.05$), and cue consistency ($\beta = -0.20$, $p < 0.05$) were all significant predictors in the model. While the model was statistically significant [F(5, 186) = 23.23, $p < 0.001$, $r^2 = 0.38$], the r^2 value only increased by 0.01. The ANOVA test between model two and model three was significant ($p < 0.05$) indicating that the current model significantly improved the predictive fit.

Hypothesis Two: Habit Model

In block one (see Figure 5, Appendix A), PBC ($\beta = 0.38$, $p < 0.001$) was found to be a significant predictor of habit. The model including PBC as a predictor was a significantly better fit for the data [F(1, 190) = 31.73, $p < 0.001$, $r^2 = 0.14$]. The baseline model explained 14% of the variance in habit.

Affective attitude was added to the second block as a predictor of habit (see Figure 6, Appendix A). Both PBC ($\beta = 0.14$, $p < 0.05$) and affective attitudes ($\beta = 0.53$, $p < 0.001$) were statistically significant predictors and the model itself was significant [F(2, 189) = 54.40, $p < 0.001$, $r^2 = 0.37$]. The model explained an additional 23% of the variance in habit compared to the block one. An ANOVA test showed that the addition of affective attitudes significantly improved model fit ($p < 0.001$).

In the final block (see Figure 7, Appendix A), cue consistency was added as a predictor of habit. In this model, affective attitudes ($\beta = 0.48$, $p < 0.001$) and cue consistency ($\beta = 0.32$, $p < 0.001$) were statistically significant, but PBC ($\beta = 0.10$, $p = 0.11$) was not. The full model was significant [$F(3, 188) = 54.43$, $p < 0.001$, $r^2 = 0.46$] and explained an additional 9% of the variance in habit, totaling 46%. An ANOVA test showed that the model fit the data better when cue consistency was included as a predictor ($p < 0.001$).

Chapter Five: Discussion

Behavior change theories have yet to incorporate cues into their models despite conceptual support through habits (Wood & Rünger, 2016). In Chapter One, prompt cues were found to be especially promising in increasing physical activity, but very few studies grounded their interventions in theory. The natural conclusion would be to encourage researchers to ground their cue interventions in theory, however, the only prominent behavior change theory to include cues is the HBM. Therefore, we need to explore whether cues can be integrated into modern theories to encourage theory-based research. The purpose of this study was to test whether (a) the Dual Process approach predicted MVPA and (b) cue consistency predicted habit. We tested cue consistency alongside other recognized determinants to examine the strength of the relationship. The results showed that the habit and intention were highly significant predictors of MVPA. The addition of affective attitudes and PBC explained an additional 6% of the variance in MVPA. While including cue consistency in the model significantly improved model fit, there was only an additional 1% of the variance explained. However, when testing cue consistency as a predictor of habit, the addition of cue consistency was highly significant ($p < 0.001$) and explained an additional 9% of the variance in habit. Thus, we can infer that cue consistency has a significant role in predicting habit and some role in predicting MVPA.

The first model tested the effect of habit and intention on MVPA. Both predictors were significant in the model and had large positive coefficients indicating that increases in either would yield a strong increase in MVPA. The model explained 31% of the variance in MVPA. These results add to the growing body of research supporting the

Dual Process approach (Allom et al., 2016; Arnautovska et al., 2017; Hagger & Chatzisarantis, 2014; Kaushal & Rhodes, 2015) and highlight the importance of including automatic processes in behavior change models.

In addition to the Dual Process approach, cue consistency was found to predict MVPA. Cue consistency had a significant negative coefficient suggesting that higher scores of cue consistency result in a decline in MVPA. The inclusion of cue consistency did improve model fit but only had a very small increase in the proportion of the variance explained. These results contradict the success of the interventions found in Chapter One, where the vast majority of cue-based interventions led to increased physical activity behavior. Pimm et. al (2016) did find cues to location, mood, and type of activity cues to negatively impact behavior. While these results were non-significant in their sample, it is possible that cue consistency achieved significance in our sample because we measured it collectively. Given that we found cue consistency to have a significant negative effect on MVPA but only an additional 1% proportion of the variance explained, our study should be replicated to produce a definitive conclusion on whether (a) cue consistency significantly predicts MVPA and (b) the direction of the relationship.

The key difference in this study may be that research thus far has investigated specific cues as consistently present rather than cue consistency as a collective construct. When specific cues are evaluated individually they have been found to predict both automaticity and behavior (Pimm et al., 2016; Schumacher et al., 2019, 2021; Wood et al., 2005). Our results support the predictive pathway from cues to habit. Cue consistency was a highly significant predictor of habit and accounted for an additional 9% of the variance in the model that included affective attitudes and PBC. In terms of the association strength, cue consistency (β = 0.32) was stronger than PBC (β = 0.10) but not as strong as affective attitudes (β = 0.47). While there are no other studies that have investigated cue consistency as a construct, this relationship is stronger than those found for the consistency of an individual cue in previous research. Kaushal and Rhodes (2015) found that temporal consistency (β = 0.22) was significantly associated with habit formation but to a lesser extent than other determinants. Likewise, Pimm et al. (2016) found every cue had a coefficient between -0.07 and 0.11 when tested against habit formation. Our results find a stronger relationship between cue consistency and habit when the consistency of cues is measured collectively. These results support our hypothesis that cues predict habit and align with conceptual predictions (Wood & Rünger, 2016). Given that cue consistency was a strong predictor of habit, cue consistency should be incorporated into the Dual Process approach. Future cue interventions should be guided by the Dual Process approach to create better informed interventions and further evaluate whether cue consistency is a strong predictor of habits.

Strengths/Weaknesses

The study that we conducted has particularly useful findings since we collected a large sample of data. The final analysis included 192 measurements of each variable, increasing the power of our analyses. Additionally, data was collected prospectively, at two time points, to increase the reliability of the results. Finally, data was collected using highly reliable measures which strengthens the validity of our results.

A key limitation of this research was that data was collected purely by survey. Self-report measures, while often validated, are inconsistent with objective measures of physical activity (Prince et al., 2008), and can collect inflated MVPA data (Ferrari et al., 2020). The use of accelerometers would have improved the reliability of the physical activity data. Future research should look to measure physical activity objectively.

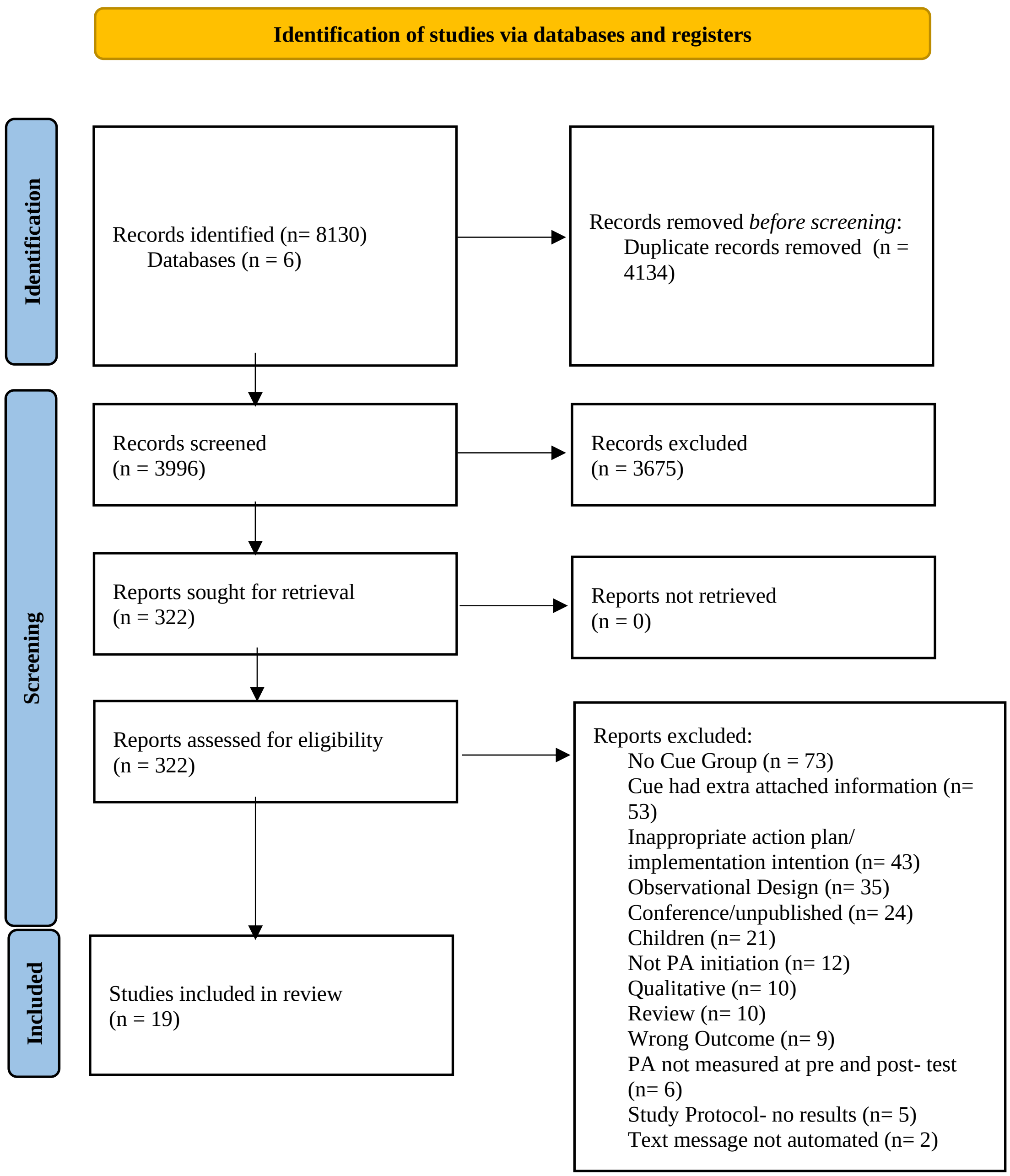
Chapter Six: Conclusion

Cues have demonstrated their efficacy in behavior change but need to be incorporated into theories to generate theory-based cue interventions. Traditionally, cues and consistency have been evaluated separately, however, the cue consistency construct is parsimonious. Previous research has analyzed the consistency of cues individually using the cue consistency measure included in our study. Our results suggest that the measure can reveal meaningful findings when analyzed as a comprehensive measure of cue consistency, particularly in regard to habit. In addition, this study sought to evaluate whether cue consistency can be included in an extension of the Dual Process approach. The results show that cue consistency directly predicts exercise behavior and habit and supports the inclusion of the construct in behavior change theories. Future research should design interventions to boost exercise behavior using cue consistency as a facilitator of habits. These studies should serve as replication tests to validate our findings and establish the role of cues in behavior change theories.

Appendices

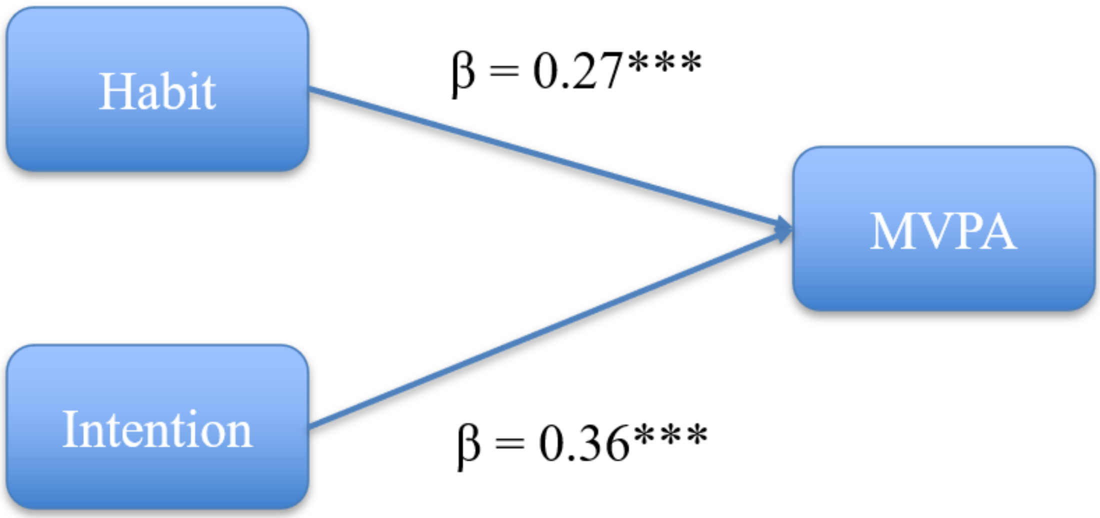
Appendix A

Figure 1: PRISMA Flowchart



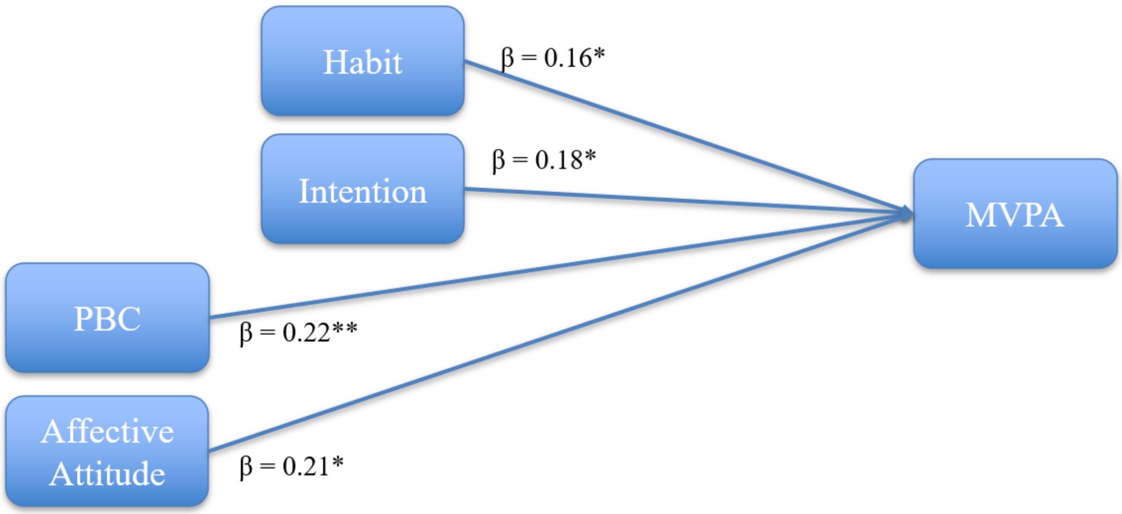
Note: Some studies may have more than one reason for exclusion

Figure 2: Hypothesis One- Block One



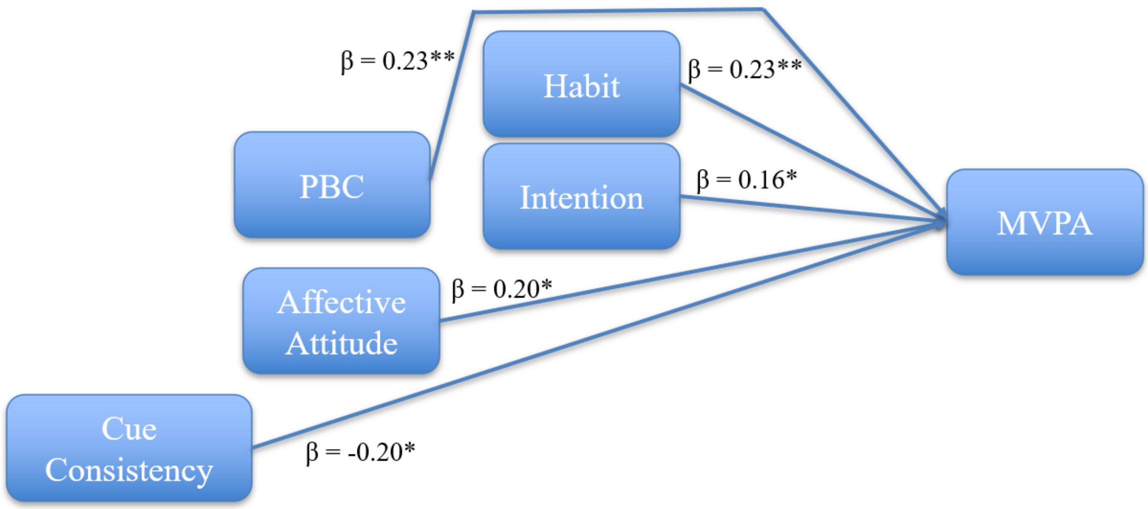
Note: R^2 = 0.31. *p < .05. **p < .01. ***p < .001.

Figure 3: Hypothesis One- Block Two



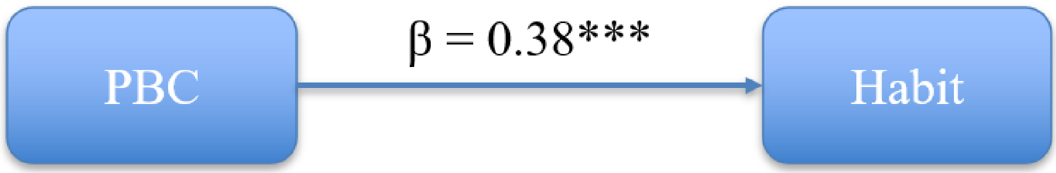
Note: $R^2 = 0.37$. **p* < .05. ***p* < .01. ****p* < .001.

Figure 4: Hypothesis One- Block Three



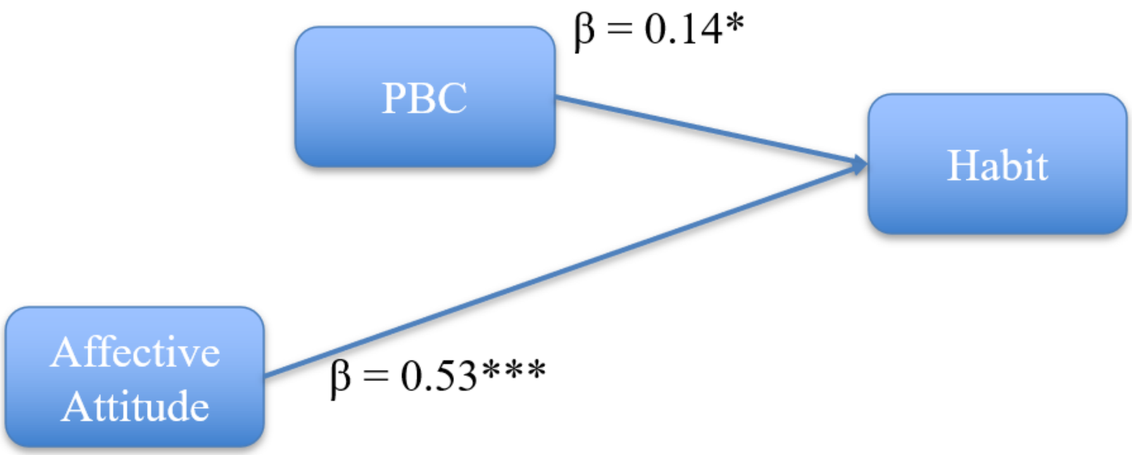
Note: $R^2 = 0.38$. *p < .05. **p < .01. ***p < .001.

Figure 5: Hypothesis Two- Block One



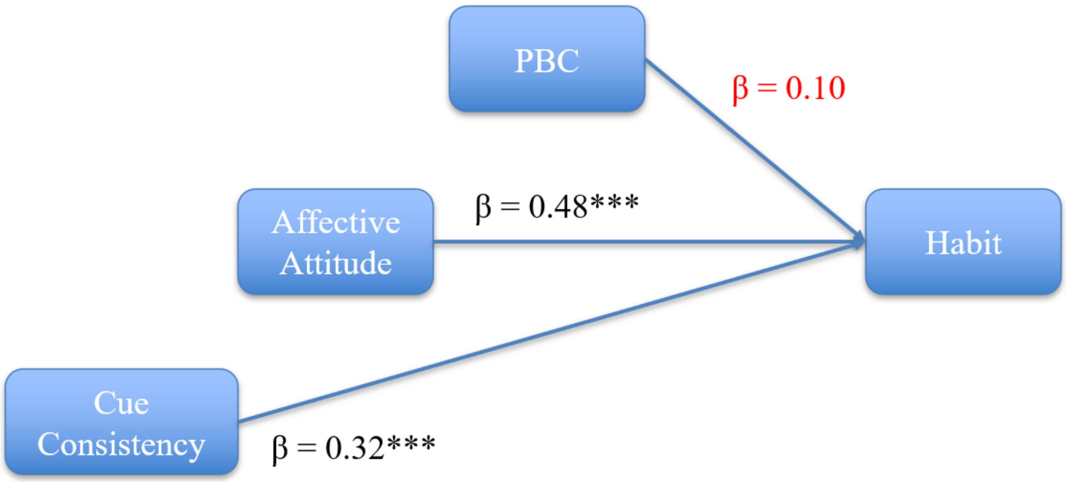
Note: $R^2 = 0.14$. $^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Figure 6: Hypothesis Two- Block Two



Note: $R^2 = 0.37$. *$p < .05$. **$p < .01$. ***$p < .001$.

Figure 7: Hypothesis Two- Block Three



Note: $R^2 = 0.46$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 1: Characteristics of Included Studies

Author(s)	Country in which the study conducted	Aim of study	Study design	Study duration	Total number of participants	Theory Application	Population description
(Antoine Parker & Ellis, 2016)	United States	To determine if electronic prompts delivered by cell phones would increase minutes of aerobic PA in adults aged 50+.	Incomplete within-subjects crossover design	4 weeks	28		Age 50+
(Cheung et al., 2012)	Hong Kong	Examine the effectiveness of a pedometer-based intervention combining the use of pedometers with SMS messages.	Intervention design	12 weeks	88	Social Cognitive Theory (for text message context in PED-Goal group; not relevant to this review)	Age 25-54 and not physically active.
(Cotten & Prapavessis, 2016)	Canada	To determine whether a text message intervention would increase the frequency and length of breaks from sitting, time spent standing, and time spent in light and moderate intensity PA in university students.	RCT	6 weeks	82		University students

(Da Silva et al., 2016)	UK	"Evaluated the technical feasibility of using the CueS device to collect, download and display activity data whilst integrated into an upper limb stroke therapy programme and describes how patients responded to the prompting mechanism"	Single arm intervention study	4 weeks	7		New stroke-related upper limb motor deficit, mean time post stroke of 13 days.
(Eves & Puig-Ribera, 2019)	Spain, the Netherlands, UK	To assess whether disrupting habitual escalator use with an environmental cue influences stair climbing.	Quasi-experimental, interrupted time series	17 weeks	115,062		General Public, children and individuals with children were excluded.
(Foccardi et al., 2021)	Italy	Assess whether a standardized text messaging mHealth intervention post-CR would improve patients' adherence to a PA program.	Pilot RCT	3 months	32		CR patients who had completed phase 2 of their CR program
(Kaushal et al., 2017)	Canada	Assess whether a multi-process action control approach to PA promotion that focuses on habit development can increase PA relative to a control group.	RCT	8 weeks	94	Multi-Process Action Control (M-PAC)	New gym members who were not meeting PA guidelines at the time of recruitment.

(Kaushal et al., 2021)	Canada	Test if principles of habit formation would improve exercise participation among patients with Acute Coronary Syndrome.	Pilot RCT	6 months	13	Dual Process	Patients aged 50-84 at a rehabilitation center who had been diagnosed with acute coronary syndrome and were not meeting recommended PA guidelines.
(Knoll et al., 2017)	Germany	To amend shortcomings of previous research on dyadic planning by using objectively measured PA, ensuring the partner was involved in the plan, and randomizing the target person for the plan.	RCT	6 weeks	346 couples	Implementation Intentions (from Model of Action Phases)	Heterosexual couples who had been living together for 6 months or more.
(Lemanu et al., 2018)	New Zealand	Assess whether receiving text messages would lead to better adherence to exercise advice in bariatric surgery patients.	Single Blind RCT	6 weeks	102		Bariatric surgery patients
(Müller et al., 2016)	Malaysia	To determine if older Malaysians receiving an exercise booklet and weekly SMS text messages	RCT	24 weeks	43		Older adults aged 55-70 who were exercising

		exercise more than those who only receive the booklet and see if the effects of the messages are maintained when the texts stop.					once per week or less.
(Pandey et al., 2017)	Canada	To assess the impact of structured daily text message reminders on adherence to post-MI medications and exercise in two pilot RCTs.	Pilot RCT	12 months	50		Patients who had been discharged from hospital after MI and enrolled in a structured cardiac rehabilitation program.
(Prestwich et al., 2012)	UK	To test the impact of collaborative implementation intentions, implementation intentions, and partner-no-planning manipulations against a control group on physical activity and weight loss over a 6-month period.	RCT	6 months	257	Implementation Intentions (from Model of Action Phases)	Couples who were physically inactive (less than 30 minutes of exercise 5 days per week)
(Prestwich et al., 2010)	UK	To test whether interventions that paired implementation intentions with text messages cueing plans or goals increased	Randomized trial	4 weeks	149	Implementation Intentions (from Model of Action Phases) and Health Belief Model	Individuals who exercised less than 3 times per week but were not

		brisk walking in a student-based sample					medically restricted from doing so.
(Prestwich et al., 2009)	UK	To test whether the effects of implementation intentions on exercise can be strengthened by combining them with text message reminders.	Experimental Longitudinal	4 weeks	155	Implementation Intentions (from Model of Action Phases)	Students
(Tabak et al., 2014)	The Netherlands	Investigate how COPD patients respond to motivational cues and whether the response is related to cue and context characteristics. To explore whether daily activity behavior can be altered by providing ambulant feedback enhanced with motivational cues.	Intervention Design	4 weeks	15		COPD patients
(van Blarigan et al., 2022)	United States	To determine whether a digital health PA intervention is feasible and acceptable during chemotherapy, with the goal of preventing the PA decline that often occurs during treatment.	Pilot RCT	12 weeks	44		Colon/rectal cancer patients receiving chemotherapy and physically inactive (less than 150 mins

							of MVPA per week)
(Wang et al., 2015)	United States	To test the effects of a technology-based intervention delivering simple SMS prompts and Fitbit One for self-monitoring on PA.	RCT	6 weeks	67		Overweight or obese adults or those not meeting PA guidelines.
(Wooldridge et al., 2019)	United States	To examine the feasibility outcomes and obtain initial efficacy data on an intervention testing collaborative implementation intentions for PA among participants with Type 2 diabetes.	RCT	6 weeks	40 couples	Implementation Intentions (from Model of Action Phases)	Adults with Type 2 diabetes who intended to increase their PA and their relationship partner.

Note. Abbreviations: UK- United Kingdom, PA- Physical Activity, RCT- Randomized Controlled Trial, MVPA- Moderate-Vigorous Physical Activity, SMS- Short Message Service, COPD- Chronic Obstructive Pulmonary Disease, MI- Myocardial Infarction, PED-Pedometer, CR- Cardiac Rehabilitation, N/A- Not Applicable.

Table 2: Data Extraction: Intervention Contents and Study Outcomes

Author(s)	Cue feature	Outcome Variable	Measure	Description of results	Notes	EPHPP Rating
(Antoine Parker & Ellis, 2016)	SMS reminder text stating "Don't forget to do cardio today". The text was sent in the morning, 3 days per week. In the evening, a text was sent stating "did you do your exercise today?".	Minutes of aerobic PA	Electronic Physical Activity Participation form	When in treatment condition weekly aerobic PA increased by M=96.88 (SD=62.9) compared to control (M=71.68, SD=40.98). Within-subjects ANOVA showed significant differences between conditions on total PA: Wilks' Lambda= 0.82, F(1,27)=5.76, *p*=0.024, np^2=0.18	Each group received the intervention for 2 weeks and the control condition for the other two weeks.	WEAK
(Cheung et al., 2012)	PED group- received only a pedometer as the motivational tool.	Daily Step Count	Pedometer	No significant difference between the no pedometer control and the PED group. A significant effect of time on step count across all groups (control, PED, pedometer+goal setting SMS, pedometer + PA benefits SMS):		WEAK

				$F(1,84)=5.6$, $p<0.05$, partial n^2=0.06. Post hoc tests did not reveal significant results for PED group. PED group increased steps by 816 from baseline to week 12. Control decreased by 413. No indication of significance.		
(Cotten & Prapavessis, 2016)	Text messages containing tips and reminders to be active and break up sitting time. E.g. "Don't forget to get up every hour and walk around for 5 minutes." Some texts contained PA challenges which got increasingly more difficult. E.g. get up every hour for 5 minutes for the next 7 days.	Time spent in light and moderate PA	SLIPA questionnaire and short form 7 day PA recall questionnaire.	No significant results. Intervention group: LIPA +50.07min/day, MIPA +13.03min/day Control group: LIPA -24.27min/day, MIPA +3.06min/day No group x time interactions for any outcomes.	Despite descriptive data changes, there are no significant results.	MODERATE
(Da Silva et al., 2016)	The CueS wristband was worn for 12 hours per day and periodically prompted	Completed therapy program and	Daily log sheets and Accelerometer	Following the prompt, an increase in mean activity levels occurred ranging from		WEAK

	the wearer in the form of a vibration. The individual could set the prompt frequency (e.g. every 2h). The wearer would be prompted if upper limb activity in the selected time window did not meet their target (5%, 25%, or 50% above median hourly activity). Frequency and activity targets were adjusted twice weekly during therapy reviews. Participants received a median of 4 prompts per day.	upper limb activity		11% to 29% with a median of 19.8% (*p*=0.03) compared to the previous hour.		
(Eves & Puig-Ribera, 2019)	Point-of-choice prompts between the escalator and the stairs. Either an artistic design alone or the design with the message, "Take the stairs. 7 minutes of stair climbing a day protects your heart/health", displayed on it. The	Choosing to use the stairs or escalator	Observers coded pedestrian choices	All results are OR that control for the direction of approach and volume of pedestrian traffic and demographics. Study 1 showed baseline vs. design-alone had no effect (OR= 1.21, p=0.69) but design + message had an OR of 0.55	3 studies were reported. Study 1 used a 2-week baseline, 2-week design alone, and 2-week design + message. This established that the design alone was not	STRONG

	goal was to pair the message with the design and eventually present the design alone as the learned cue.		(*p*=0.04) indicating a lower chance of using the escalator. Study 2 found that the design-alone increased the likelihood of choosing the stairs (OR= 0.84, *p*<0.001) after exposure to the design + message (OR= 0.69, *p*< 0.001). The second baseline had a lower likelihood of escalator use compared to the first baseline (OR=0.79, *p*<0.001) but the second baseline had a higher likelihood than the design + message phase (OR=1.14, *p*<0.01). Study 3 found that the design + message phase has a lower likelihood of escalator use at both locations [OR= 0.74 (*p*<0.001) and 0.64 (*p*<0.001)]. The design alone was found to produce	influencing behavior, and the design + message intervention was. Study 2 used a 2-week baseline, 5-week design + message, 3-week gap, 2-week baseline, 3 weeks design-alone, and 1-week baseline. Study 3 assessed whether an artistic design or color alone would be sufficient to replicate the results from study 2. At two locations the authors organized a 2-week baseline,

				similar responses to that of the design + message condition (art- OR=1.12, *p*<0.001; color- OR=1.17, *p*<0.001). The design alone had a lower likelihood at the location using the artistic design (OR=0.82, *p*<0.05) while the other did not due to a low second baseline.	5-week design + message, 4-week gap, 1-week baseline, 4-week design-alone.	
(Foccardi et al., 2021)	A text message was sent at 8:30 am stating “The rehabilitation cardiology service reminds you to carry on with your PA program as indicated in the prescription.”	Physical Activity time (minutes/week)	Global Physical Activity Questionnaire (GPAQ)	Moderate recreational activity: CG non-significantly changed from 150 (98.4) mins/week to 166.9 (158.5) mins/week (*p*>0.05). IG changed significantly from 119.4 (111.4) mins/week to 380.9 (167.4) mins/week (*p*<0.001). There was a 244.7 min/week between- group difference in PA change (*p*<0.001)		STRONG

(Kaushal et al., 2017)	Participants were encouraged to find their own cue which would initiate a habitual preparatory phase that concludes with exercising. The example given was putting gym clothes on your bed before work so that when you return home they will be present and cue you to exercise until they are removed. This training was conducted in week 1 and followed up on in week 4.	Time spent in MVPA	Accelerometer and Godin Leisure Time Exercise Questionnaire	At week 8, both groups demonstrated increases in MVPA minutes per week [intervention = 131.46 (SD=81.25) - 185.26(112), control = 127.29(72) - 148.52(68.95)]. The intervention group experienced greater changes in MVPA [$F(1,91)= 4.13$, $p=0.04$] compared to the control at week 8. The magnitude of change was calculated to be d=0.39 for accelerometer and 0.53 for self-report.	STRONG
(Kaushal et al., 2021)	Participants were guided in establishing their preparatory exercise habits by encouraging a consistent routine that used cues to prompt exercise.	Exercise Activity Time	Leisure Time Exercise Questionnaire	Group differences at month 3 were not significant [$F(3, 12) = 0.89$, $p = 0.38$ ($\eta^2 = 0.10$)], d = 0.10. The experimental group increased in exercise time by M=228.2 minutes	STRONG

				(SD= 112.45) compared to the control which increased by M=151.17 minutes (SD= 112.22). This was non-significant [F (3,12) = 2.42, p = 0.16 (η^2 = 0.23)] but had an effect size of d= 0.61.		
(Knoll et al., 2017)	"If... then..." implementation intention. Dyadic planning group had to involve the partner while the individual planning group did not; instead creating an individual implementation intention.	Daily PA	Accelerometer	No significant results for those targeted by the implementation intention.		STRONG
(Lemanu et al., 2018)	Daily text messages that were designed to remind or encourage adherence to exercise advice.	Exercise activity (METs) and minutes/week	IPAQ	Mean weekly METs- baseline: 745.8(1265.3), post-intervention: 1196.9(1662.4). Mean weekly exercise minutes- baseline: 188.9(299.1), post-	All increases from baseline to post-intervention were statistically significant.	MODERATE

				intervention: 279.9(283.7).		
(Müller et al., 2016)	Daily text messages that contained an instruction to exercise and praise for engagement. This continued for 12 weeks. Participants did not receive texts between week 12 and 24.	Weekly exercise frequency and METs	Exercise log and IPAQ short form	There was no significant main or interaction effect for METs at any time point. Week 1-12: Text arm exercised 3.74 times per week. The mean difference between groups was 1.21, SD=1.34, and was significant (t=2.3, *p*=0.03, d=0.76). When controlled for baseline self-efficacy, text messaging strengthened its effect on exercise frequency [F(1,36)=6.81, *p*=0.01]. Week 12-24: Significant decrease of 0.68 sessions per week in SMS group [F(1,36)=8.93, *p*=0.005]. There was no significant change		STRONG

				in the control. There was no significant difference between groups for exercise frequency.		
(Pandey et al., 2017)	Text message reminders were sent 4 times daily at 7:30 am, 12 pm, 6 pm, and 9 pm. The text read "Please remember to exercise for 30 minutes today."	Average number of days per month that a patient exercised	Exercise log	Patients in the intervention group exercised by 4.2 more days per month than the control (13.1-17.2, *p*<0.001). Intervention group patients exercised 4 more hours per month (12.5-8.5 hours, *p*<0.001).	Statistics do not offer within-group analyses. Figure 2 illustrates a steady decline in exercise days for the control while the exercise group maintains their level.	WEAK
(Prestwich et al., 2012)	Implementation intentions that identified IF (I/we're in situation X) THEN (I/we will do Y). These were either made with a partner (collaborative group), on their own but asked to recruit a partner (partner-only group), for themselves only (implementation	Physical activity	IPAQ and SWET	Collaborative group change in PA: 1 month: F(3, 168)=2.67, *p*=.02; 3 months: F(3, 159)=2.32, *p*=.04; 6 months :F(3, 159)=1.97, *p*=.06. The collaborative group was physically active more frequently at 1 month [vs.		STRONG

	intention group), or a no planning control group.			control, *p*=.003, d=.63 (CI, d=.24-.99); vs. implementation intention, *p*=.03, d=.44 (CI, d=.04-.83); vs. partner-only, *p*=.02, d=.47 (CI, d=.09-.84)] and 6 months [vs. control, *p*=.02, d=.49 (CI, d=.12-.86); vs. implementation intention, *p*=.02, d=.49 (CI, d=.08-.88); vs. partner-only *p*=.05, d=.38 (CI, d=.00-.75)] Main effect of condition at 6 months [F(3,141)=3.2, *p*=0.03]. Control reported lower METs compared to implementation intention group (*p*=0.06, d=0.36) Partner-only group reported lower METs than the control (*p*=0.004, d=-0.66)	
(Prestwich et al., 2010)	Participants in the implementation intention + SMS group	Walking and exercise behavior	SWET	There was a significant change in brisk walking [F(2,	STRONG

	formed implementation intentions in the "if... then..." format with the aim of walking 5 times per week for 30 minutes per day. In addition, they were sent text messages reminding them of their implementation intentions. They could choose when, how frequently, and the content of the messages they would receive.			130)=3.12, *p*=0.048] but not a significant change in total exercise [F(2,130)=2.63, *p*=0.076]. 45% in the implementation intention + SMS group increased the number of days they met guidelines by at least 2 or more days compared to 22% in control. Implementation intention + SMS vs control for the change in brisk/fast walking: d=0.49, *p*=0.04 (95% CI). Implementation intention + SMS exercised more than those in the control group: d=0.55, *p*=0.03 (95% CI).		
(Prestwich et al., 2009)	Implementation intention group- Instructed to form an implementation intention to be	Exercise Behavior	Questionnaire and frequency table	Implementation intention group increased in exercise behavior from 0.74 (0.74) to 1.03 (1.06)	SMS group was not appropriate since the participants	MODERATE

	completed 3 times per week for 20 mins in the format of "when I'm in situation X, I will do Y". Individuals were able to choose their own text messages in the SMS and implementation intention + SMS groups. In the analysis, text messages from the implementation intention +SMS group were coded into reminder type (1) and not reminder type (0).			while the control increased from 0.69 (0.73) to 0.94 (0.98), a difference in increase of 0.04. No main effects for implementation intentions. Significant implementation intention x time interaction [F(1,150)=4.04, *p*=0.046, np^2=0.026]. Significant time x reminder type interaction [F(1,27)=5.36, *p*=0.03, np^2=0.166].	could decide their own text message content and was not coded like the implementation intention + SMS group.	
(Tabak et al., 2014)	Text message cue which was either neutral, encouraging, or discouraging depending on the participants' activity levels compared to their personal reference line. Cues were sent every 2 hours, 4 days per week. For example,	Daily activity	Accelerometer (activity in counts per minute was assessed 30 minutes before and after cues were received)	Significant increases in activity 5 and 10 minutes after the cue of 23% and 15% respectively. Significant relation for approaching the reference parameter. In the 30 mins before the cue, if the individual was approaching the	Individuals responded better to cues when they weren't approaching the reference line.	WEAK

	"You took more rest. Please go for a walk around the block".			activity reference line, then activity after the cue was -10 +- 66%, if they weren't approaching the reference line, activity after the cue was +194 +- 410%. When controlled for reactivity, between-group differences were significant. Encouraging cues were related to the percentage change in activity level (Rs=0.66, *p*=0.026).		
(van Blarigan et al., 2022)	Fitbit (provided for intervention and control group) and daily text messages. Texts would predominantly prompt PA but occasionally include other factors such as self-monitoring and goal setting (the general target was 150 mins of weekly MVPA).	Physical activity	Accelerometer	No patient recorded any vigorous PA at all. Both the intervention and control groups declined in moderate PA by 21.3 (SD=144.8) and 16.3 (SD=121.2) minutes per week respectively. These results are statistically non-significant.	The author notes that this study was not powered to detect change in PA but nonetheless detected a non-significant decline in PA.	MODERATE

(Wang et al., 2015)	3 messages were delivered per day for 2 weeks. This was repeated for 3 cycles. An example of message content: “Good morning [name]! This is your 9 AM reminder to do at least a 10-minute bout of moderate-to-vigorous intensity physical activity.” Participants also had a Fitbit One and had to upload data daily (also present in the control group).	Physical Activity	Accelerometer (baseline and week 6) and Fitbit (weekly)	Actigraph: No between-group differences in changes in steps or minutes of PA by intensity level. Fitbit: Significant group x time interactions for steps, fairly/very active minutes, and total active minutes. The intervention group had average higher activity levels. Significant between-group differences from baseline to week 1 (change of 1,266 vs -48 steps/day) but this was not maintained through weeks 2-6.	MODERATE
(Wooldridge et al., 2019)	Collaborative implementation intention: develop an implementation intention using the IF-THEN format where the partner plays a supportive role. E.g. "IF it is Monday after	MET-minutes per week and MVPA	IPAQ and Accelerometer	IPAQ: Significant increase in mean MET-minutes per week for collaborative implementation intention group from 649 (SD=646) to 2343 (SD=2326). Significant main effect	STRONG

	work, THEN I will ride my bike for 30 minutes while my partner prepares dinner." Regular implementation intention: formed an implementation intention based on the IF-THEN format without consulting their partner.		of study condition on PA [F(2,25)=3.90, *p*=0.034, partial n^2= 0.238]. Significant increases in collaborative implementation intention compared to individual implementation intention (*p*=0.036) and control (*p*=0.024). Accelerometer: No significant differences between or within groups.	

Note. Abbreviations in addition to Table 1A: M- Mean, SD- Standard Deviation, IPAQ- International Physical Activity Questionnaire, MET- Metabolic Equivalent of Task, SLIPA- Sedentary and Light Intensity Physical Activity questionnaire, CI- Confidence Interval, SWET- Self-Report Walking and Exercise Tables, OR- Odds Ratio.

Table 3: Demographic Characteristics of Participants Included in the Analysis (N=192)

Characteristic	N	%	M	SD
Age			47.6	18.3
Sex				
Male	35	18.3		
Female	155	81.2		
Other	1	0.5		
Race				
White	167	87.9		
Black	12	6.3		
Other	8	4.2		
Education				
High School or >	11	5.7		
Some University	28	14.7		
Bachelor’s Degree	66	34.6		
Master’s Degree	57	29.8		
Doctorate Degree	14	7.3		
Other Education	9	4.7		
Marital Status				
Never Married	73	38.2		
Married	91	47.6		
Separated/Divorced	27	14.1		
Annual Income				
< $35,000	35	18.3		
$35,001- $50,000	28	14.7		
$50,001- $75,000	32	16.8		
$75,001- $100,000	27	14.1		
$100,001- $150,000	30	15.7		
$150,001- $200,000	12	6.3		
>$200,000	12	6.3		

Table 4: Descriptive Statistics after Multiple Imputation

	M	SD
MVPA		
T1	181.51	180.95
T2	163.14	148.65
Habit		
T1	2.61	1.06
T2	2.73	1.02
Intention		
T1	3.92	1.06
T2	3.90	1.07
PBC		
T1	3.86	0.77
T2	3.87	0.85
Affective Attitude		
T1	3.4	1.09
T2	3.37	1.13
Cue Consistency		
T1	3.05	0.85
T2	3.01	0.92

Note: Higher scores indicate stronger levels of each construct.

Table 5: Bivariate Correlations of Variables after Multiple Imputation

	T1_ cue	T2_ cue	T1_ aff	T2_ aff	T1_ hab	T2_ hab	T1_ int	T2_ int	T1_ mvpa	T2_ mvpa	T1_ pbc	T2_ pbc
T1_ cue	1.00	0.66	0.25	0.26	0.45	0.42	0.17	0.17	0.16	0.16	0.21	0.26
T2_ cue	0.66	1.00	0.27	0.25	0.40	0.40	0.31	0.22	0.04	0.14	0.34	0.36
T1_ aff	0.25	0.27	1.00	0.87	0.59	0.49	0.59	0.46	0.47	0.50	0.46	0.52
T2_ aff	0.26	0.25	0.87	1.00	0.59	0.55	0.61	0.52	0.44	0.49	0.44	0.51
T1_ hab	0.45	0.40	0.59	0.59	1.00	0.76	0.52	0.43	0.42	0.50	0.39	0.41
T2_ hab	0.42	0.40	0.49	0.55	0.76	1.00	0.48	0.50	0.40	0.47	0.43	0.49
T1_ int	0.17	0.31	0.59	0.61	0.52	0.48	1.00	0.67	0.46	0.47	0.53	0.55
T2_ int	0.17	0.22	0.46	0.52	0.43	0.50	0.67	1.00	0.45	0.47	0.41	0.46
T1_ mvpa	0.16	0.04	0.47	0.44	0.42	0.40	0.46	0.45	1.00	0.84	0.48	0.48
T2_ mvpa	0.16	0.14	0.50	0.49	0.50	0.47	0.47	0.47	0.84	1.00	0.53	0.55
T1_ pbc	0.21	0.34	0.46	0.44	0.39	0.43	0.53	0.41	0.48	0.53	1.00	0.85
T2_ pbc	0.26	0.36	0.52	0.51	0.41	0.49	0.55	0.46	0.48	0.55	0.85	1.00

Appendix B

Search Strategy for PubMed

((exercise[MeSH Terms]) OR ("physical activity"[Title/Abstract] OR running[Title/Abstract] OR "physical conditioning"[Title/Abstract] OR walking[Title/Abstract] OR biking[Title/Abstract] OR cycling[Title/Abstract] OR jogging[Title/Abstract] OR "resistance training"[Title/Abstract])) AND ((cues[MeSH Terms]) OR (association[MeSH Terms]) OR ("conditioned stimulus"[Title/Abstract] OR cue[Title/Abstract] OR cues[Title/Abstract] OR Cueing[Title/Abstract] OR "text messag*"[Title/Abstract]) OR ("implementation intention"[Title/Abstract] OR “implementation intentions”[Title/Abstract] OR “action plan”[Title/Abstract] OR “action plans”[Title/Abstract] OR "action planning"[Title/Abstract])) NOT ("food cue"[Title/Abstract] OR "retrieval cue"[Title/Abstract] OR "cued recall"[Title/Abstract]) AND (random*[Title/Abstract] OR "comparative stud*"[Title/Abstract] OR clinical NEAR/3 trial*[Title/Abstract] OR research NEAR/3 design[Title/Abstract] OR evaluat* NEAR/3 stud*[Title/Abstract] OR prospectiv* NEAR/3 stud*[Title/Abstract] OR (singl*[Title/Abstract] OR doubl*[Title/Abstract] OR trebl*[Title/Abstract] OR tripl*) NEAR/3 (blind*[Title/Abstract] OR mask*[Title/Abstract]) OR intervention[Title/Abstract] OR control NEAR/3 group*[Title/Abstract] OR allocated[Title/Abstract] OR experiment* NEAR/3 design[Title/Abstract] OR "cross-over"[Title/Abstract] OR program*[Title/Abstract])

Limiters: English, Humans

Search Strategy for Embase

('exercise'/mj OR 'exercise':ti,ab OR 'physical activity':ti,ab OR running:ti,ab OR 'physical conditioning':ti,ab OR walking:ti,ab OR biking:ti,ab OR cycling:ti,ab OR jogging:ti,ab OR 'resistance training':ti,ab) AND ('conditioned stimulus':ti,ab OR 'cue'/mj OR cue*:ti,ab OR 'text messag*':ti,ab OR ('implementation intention*':ti,ab OR 'action plan*':ti,ab) NOT ('food cue':ti,ab OR 'retrieval cue':ti,ab OR 'cued recall':ti,ab) AND (random*:ti,ab OR 'comparative stud*':ti,ab OR ((clinical NEAR/3 trial*):ti,ab) OR ((research NEAR/3 design):ti,ab) OR ((evaluat* NEAR/3 stud*):ti,ab) OR ((prospectiv* NEAR/3 stud*):ti,ab) OR (((singl* OR doubl* OR trebl* OR tripl*) NEAR/3 (blind* OR mask*)):ti,ab) OR intervention:ti,ab OR ((control NEAR/3 group*):ti,ab) OR allocated:ti,ab OR ((experiment* NEAR/3 design):ti,ab) OR 'cross-over':ti,ab OR program*:ti,ab) AND [humans]/lim AND [english]/lim

Search Strategy for PsycINFO/SPORTDiscus

(DE "Exercise" OR TI(exercise OR "physical activity" OR running OR "physical conditioning" OR walking OR biking OR cycling OR jogging OR "resistance training") OR AB(exercise OR "physical activity" OR running OR "physical conditioning" OR walking OR biking OR cycling OR jogging OR "resistance training")) AND (DE cues OR DE "Contextual associations" OR TI(“conditioned stimulus” OR cue* OR "text messag*" OR “implementation intention*” OR "action plan*") OR AB(“conditioned stimulus” OR cue* OR "text messag*" OR “implementation intention*” OR "action plan*")) NOT ("food cue" OR "retrieval cue" OR "cued recall") AND (random* OR "comparative stud*" OR clinical NEAR/3 trial* OR research NEAR/3 design OR evaluat* NEAR/3 stud* OR prospectiv* NEAR/3 stud* OR (singl* OR doubl* OR trebl*

OR tripl*) NEAR/3 (blind* OR mask*) OR intervention OR control NEAR/3 group* OR allocated OR experiment* NEAR/3 design OR "cross-over" or program*)

Limiters: English, Peer-reviewed, do not apply equivalent, human

Search Strategy for Scopus

TITLE-ABS(exercise OR "physical activity" OR running OR "physical conditioning" OR walking OR biking OR cycling OR jogging OR "resistance training") AND TITLE-ABS("conditioned stimulus" OR cue* OR "text messag*" OR "implementation intention*" OR "action plan*") AND TITLE-ABS(random* OR "comparative stud*" OR (clinical W/3 trial*) OR (research W/3 design) OR (evaluat* W/3 stud*) OR (prospectiv* W/3 stud*) OR ((singl* OR doubl* OR trebl* OR tripl*) W/3 (blind* OR mask*)) OR intervention OR (control W/3 group*) OR allocated OR (experiment* W/3 design) OR "cross-over" OR program*) AND NOT TITLE-ABS("food cue" OR "retrieval cue" OR "cued recall") AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"re")) AND (LIMIT-TO (LANGUAGE,"English"))

Search Strategy for Google Scholar

"cues" exercise OR "Implementation intention" OR "action planning" exercise OR physical activity trial OR experiment OR program OR evaluation OR comparison

Appendix C

Moderate-to-Vigorous Physical Activity Time

Adapted from Godin et al. (1986):

We would like you to recall your average, weekly exercise time over the past 2 weeks. Specifically, over the past 2 weeks, how many times per week, on average, did you exercise and what was the duration?

When answering these questions please:

- Note that the main difference between the three categories is the intensity of exercise.
- Write the average frequency on the first line and the average duration on the second line.

Items:

Strenuous Exercise- (Heart beats rapidly, sweating)

Number of times per week: _______

Average minutes per session: _______

Moderate Exercise – (Not exhausting, light perspiration)

Number of times per week: _______

Average minutes per session: _______

Habit

Adapted from Kaushal, Rhodes, Meldrum et al. (2017):

The following questions ask how you feel about the preparing to exercise. The exercise preparatory phase includes all of the activities you would regularly perform before each exercise session at home (e.g., putting on workout clothes, setting up your exercise space). This measure uses a five-point Likert scale ranging from “strongly disagree” to “strongly agree”. Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5).

Items:

- When I prepare to exercise, I do it automatically.
- I prepare to exercise without having to consciously remember.
- I prepare to exercise without thinking.
- I start preparing to exercise before I realize I am doing it.

Intention

Adapted from Ajzen (2019):

The following questions assess your physical activity intentions. This measure uses a five-point Likert scale ranging from “strongly disagree” to “strongly agree”. Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5).

Items:

- I intend to be regularly physically active.
- I expect to be regularly physically active.

Perceived Behavioral Control

Adapted from Ajzen (2019):

Please answer the following regarding your exercise experience. This measure uses a five-point Likert scale ranging from “strongly disagree” to “strongly agree”. Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5).

Items:

- I have good athletic ability.

- I have considerable skill when it comes to exercising.
- I will have the opportunity to exercise over the next month if I really wanted to.
- I have enough free time in my schedule to be regularly active if I was really motivated.
- Exercising is under my control.
- Achieving at least 150 minutes of exercise per week is completely under my control.
- Exercising more than 150 minutes a week would be easy for me to do.

Affective Attitude

Adapted from Cid et al. (2018):

Please answer the following regarding your exercise experience. This measure uses a five-point Likert scale ranging from "strongly disagree" to "strongly agree". Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5).

Items:

- I exercise because it is fun.
- I enjoy my exercise sessions.
- I find exercise a pleasurable activity.
- I get pleasure and satisfaction from participating in exercise.

Cue Consistency

Adapted from Pimm et al. (2016):

This measure uses a five-point Likert scale ranging from "strongly disagree" to "strongly agree". Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5).

Items:

Each time I start to engage in physical activity…

- It is the same time of day.
- I am around the same people.
- I do the same type of activity.
- I am in the same part of my daily routine.
- I am in the same place.
- I am in the same mood or feeling state.

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