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Forms of Momentum Across Time: Behavioral and Psychological

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The behavior of an organism often exhibits biases consistent with an anticipation of future behavior. One such type of bias results in momentum-like effects in which past behavior is extrapolated or continued into the future, and examples include behavioral momentum and psychological momentum. Similarities and differences between behavioral momentum and psychological momentum are considered. It is suggested that (a) behavioral momentum and psychological momentum are closely related and reflect similar or overlapping mechanisms despite differences in experimental methodologies and nomenclatures, (b) behavioral momentum and psychological momentum reflect dynamic representation, (c) dynamic representation can operate across several different time-scales, and (d) behavioral momentum and psychological momentum might be related (via processes involved in dynamic representation) to other types of momentum-like effects.

Keywords: behavioral momentum, psychological momentum, temporal representation

The cognitive representation of the current action of a stimulus or the current behavior of an organism is often continued (extrapolated) forward in ways that reflect the anticipated subsequent action or behavior of that stimulus or organism. This continuation is found with different types of stimuli, and it is often described as or attributed to a momentum-like effect. Some types of momentum-like effects operate on a brief time-scale and appear primarily spatial, and examples include representational momentum (e.g., Freyd and Finke, 1984), operational momentum (e.g., McCrink, Dehaene, and Dehaene–Lambertz, 2007), and attentional momentum (e.g., Pratt, Spalek, and Bradshaw, 1999). Other types of momentum-like effects operate on a longer time-scale and appear primarily temporal, and examples include behavioral momentum (e.g., Nevin, Mandell, and Atak, 1983) and psychological momentum (e.g., Vallerand, Colavecchio, and Pelletier, 1988).

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The shorter time-scale and more spatial momentum-like effects were reviewed in Hubbard (2014), and the longer time-scale and more temporal momentum-like effects of behavioral momentum and psychological momentum are reviewed in this paper. One purpose here is to examine similarities and differences of behavioral momentum and psychological momentum and to consider whether these two effects might reflect similar or overlapping mechanisms. A second purpose is to consider whether behavioral momentum and psychological momentum are consistent with the notion of dynamic representation.

Although behavioral momentum and psychological momentum are considered in more detail below, it would be helpful to begin with a brief description of each of these two momentum-like effects. Behavioral momentum and psychological momentum are each based on an analogy with physical momentum. Physical momentum is the product of velocity and mass, and as specified by Newton's laws, an object in motion continues in motion at the same velocity and in the same direction until acted upon by some other force. Behavioral momentum is a tendency for learned behaviors to continue until acted upon by some opposing force (e.g., extinction, satiation); more specifically, behavioral momentum involves resistance to change of a learned behavior in which response rate is analogous to velocity and that behavior's resistance to change is analogous to mass. Similarly, psychological momentum is a tendency to believe that a subsequent behavior is more likely to be consistent with previous behavior; more specifically, psychological momentum involves perception of whether success or failure (e.g., winning or losing a game, respectively) is more or less easily achieved as a function of recent success or failure. Behavioral momentum has been most often studied with laboratory animals (mostly pigeons) or behavior analysis of humans (mostly individuals with developmental or learning disorders) in clinical or applied settings, whereas psychological momentum has been most often studied with verbal reports regarding observation of or participation in human sport competition.

One conclusion that will be reached is that behavioral momentum and psychological momentum reflect similar or overlapping mechanisms. These mechanisms are not tied to a literal physical momentum, but instead reflect a more abstract notion of change in which temporal information is an intrinsic and necessary component of the representation of an action or behavior (cf. the mechanism of representational momentum in Finke, Freyd, and Shyi, 1986; Freyd, 1987). Along these lines, whether the term "behavioral momentum" or "psychological momentum" is used often appears to depend on whether the data involve observable behavior or verbal reports of subjective experience. A second conclusion that will be reached is that behavioral momentum and psychological momentum involve dynamic representation, and views of dynamic representation that arise from consideration of other momentum-like effects should be expanded to include the longer time-scales of behavioral momentum and psychological momentum. Parts I and II review research on behavioral momentum and psychological momentum, respectively, and use the same general framework (involving characteristics of the target, context, and observer) as Hubbard's (2014) discussion of spatial momentum-like effects.[1] Part III compares properties of behavioral momentum and properties of psychological momentum and considers whether these momentum-like effects involve similar mechanisms and are consistent with characteristics of dynamic representation. Part IV provides some brief conclusions.

Part I: Behavioral Momentum

Just as a physical body continues in motion until acted upon by an outside force, ongoing behavior maintained by constant conditions of reinforcement continues at a steady rate until acted upon by an external variable (Nevin et al., 1983). Baseline response rate under constant conditions is considered equivalent to initial velocity, and resistance of behavior to change is considered equivalent to mass (Nevin, 1988, 2012); therefore, behavioral momentum is the product of response rate (analogous to velocity) and resistance to change (analogous to mass). More specifically, response–reinforcer (operant) relationships correspond to velocity, and stimulus–reinforcer (Pavlovian) relationships correspond to mass (Nevin, 1992). In general, higher reinforcement rates or magnitudes produce more persistent behavior. Behavioral momentum has its roots in the study of learning, and studies of behavioral momentum typically use the methodologies, statistical techniques, and language of learning theory. A complete review of this literature is beyond the scope of this article (for reviews, see Dube, Ahearn, Lionello–DeNolf, and McIlvane, 2009; Nevin and Grace, 2000; Nevin and Shahan, 2011), but a selective review of behavioral momentum that focuses on primary findings and highlights similarities to psychological momentum is presented.

Target

In studies of behavioral momentum, the term "target" usually refers to a specific behavior of an organism rather than to a stimulus external to the organism (cf. use

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[1]Spatial forms of momentum-like effects include representational momentum, operational momentum, and attentional momentum (for review, see Hubbard, 2014). Although an understanding of these spatial forms of momentum-like effects is not necessary for the consideration of temporal forms of momentum-like effects (i.e., of behavioral momentum and psychological momentum) in this paper, such an understanding might be helpful. In brief, representational momentum involves displacement of the judged position of a moving target in the direction of anticipated motion (e.g., if a target is moving from left to right and then vanishes, observers indicate the final position of the target is slightly to the right of the actual final position). Operational momentum involves overestimation of sums in addition and underestimation of differences in subtraction (i.e., the response is further along the number line in the direction of motion than is the actual sum or difference). Attentional momentum suggests a change in the direction of movement of attention across space must first overcome momentum in the current direction of movement (e.g., more time is required to detect a target not in the current direction of movement of attention than to detect a target further along in the current direction of movement of attention).

of the term “target” in studies of representational momentum). Characteristics of the target considered here include (a) extinction, (b) the partial reinforcement extinction effect, and (c) resurgence.

Extinction. Extinction of a behavior and behavioral momentum of that behavior are inversely related. Nevin and Shahan (2011) noted that extinction disrupts responding to the target because in extinction the (a) contingency between responses and reinforcers is suspended, (b) reinforcement previously contingent upon behavior is withheld and responding declines due to generalization decrement, and (c) effects of contingency suspension and generalization decrement increase with the passage of time. Withdrawing reinforcement results in a decrease in the likelihood of a learned response (i.e., a decrease in velocity), thus resulting in a decrease in behavioral momentum. The standard view in learning theory is that resistance to extinction is a decreasing function of reinforcer rate, that is, resistance to extinction is greater with lower rates of reinforcement than with higher rates of reinforcement (see discussion of the partial reinforcement extinction effect below). However, Nevin (2012) suggests this standard view is incorrect, and that (a) resistance to extinction is an increasing function of reinforcer rate consistent with behavioral momentum (see also Nevin and Grace, 2005), and (b) the notion of behavioral momentum can account for resistance to extinction in single schedules and in multiple schedules. Relatedly, Grace, McLean, and Nevin (2003) reported that resistance to change in extinction in a response-independent reinforcement condition was consistent with behavioral momentum (see also Grace, Arantes, and Berg, 2012).

Podlesnik and Shahan (2008, 2009) examined whether reinforcement rate influenced relapse of a previously extinguished operant behavior. Pigeons on multiple variable interval schedules were provided with response-contingent food reinforcement. Additional non-contingent food reinforcement was delivered during one of the schedules. Consistent with Nevin, Tota, Torquato, and Shull (1990), baseline responses were lower and resistance to extinction was higher if additional response-independent reinforcement was presented. Following extinction, responding produced by reinstatement, resurgence, or renewal of the previously extinguished response was larger in the presence of the stimulus associated with a higher combined rate of contingent plus noncontingent reinforcement. Nevin et al. interpreted these patterns as consistent with behavioral momentum (see also Nevin and Grace, 2000), as additional reinforcement would have the effect of increasing behavioral mass (and thus increasing behavioral momentum). Podlesnik and Shahan (2009, 2010) suggested that resistance to extinction is greater in the presence of stimuli associated with a higher rate and magnitude of reinforcement. Similarly, relapse was a function of reinforcement rate, and Podlesnik and Shahan suggested an augmented version of behavioral momentum theory (including baseline reinforcement rate on relapse of responding following extinction) could account for effects of different reinforcement conditions on resistance to extinction and relapse.

Podlesnik, Bai, and Elliffe (2012) found that reinforcing an alternative response within the same context as a target response decreased the occurrence but increased the persistence of the target response (cf. Mace, McComas, Mauro, Progar, Taylor, Ervin, and Zangrillo, 2010). The increased persistence (i.e., decreased extinction) is consistent with behavioral momentum, as the alternative reinforcement (see below) should enhance the relationship between the target and the context (i.e., increase behavioral mass of the target response). Podlesnik et al. suggested one way this persistence can be decreased (i.e., extinction increased) is by training the alternative response in a different context prior to training the alternative response in the same context as the (unreinforced) target response. Podlesnik and Fleet (2014) examined whether manipulations of the stimulus–reinforcer relationship (i.e., behavioral mass) influenced resistance to change, and when additional stimuli were presented in one component of a multiple schedule, resistance to extinction decreased as stimulus duration increased. Podlesnik and Fleet suggested this was not entirely consistent with behavioral momentum theory, leading them to conclude that factors in addition to the stimulus–reinforcer relationship influenced resistance to change. A similar conclusion was reached by Arantes, Berg, Le, and Grace (2012), who noted that behavioral momentum theory did not predict that variable responding would be preferred to fixed (repetitive) responding in their (pigeon) data.

Partial reinforcement extinction effect. A key claim of behavioral momentum theory is that resistance to a change in behavior is stronger if reinforcement rate is higher than if reinforcement rate is lower (e.g., Nevin, 1988; Nevin and Grace, 2000; Nevin and Shahan, 2011). However, this claim initially appears inconsistent with the standard view noted earlier that responding extinguishes more quickly after learning under a continuous reinforcement schedule (more total reinforcement) than after learning under a partial reinforcement schedule (less total reinforcement). This latter finding has been referred to as the *partial reinforcement extinction effect*, and Nevin (1988, 2012) discussed the relationship between the partial reinforcement extinction effect and behavioral momentum in detail. Nevin (1988) presented pigeons with two schedules. Either the left key or the right key was illuminated on each trial. Left key pecks resulted in delivery of food on every trial (i.e., continuous reinforcement), whereas right key pecks resulted in delivery of food on a variable interval schedule (i.e., partial reinforcement; described in Nevin, 1992, as delivering food on 25% of trials). Responding extinguished more slowly for the right key than for the left key, and this is consistent with the partial reinforcement extinction effect. However, if prefeeding or food presentation during an intertrial interval occurred, responding extinguished more slowly for the left key (i.e., continuous reinforcement), and this is consistent with behavioral momentum.

Nevin (1988) suggested that the apparent inconsistency of the partial reinforcement extinction effect and behavioral momentum arises because most free-operant extinction data are reported as response totals, and this confounds the initial levels of responding with the rate at which responding decreases over the course of extinction (i.e., the partial reinforcement extinction effect does not take into account the velocity of behavior prior to introduction of a response disruptor). Indeed, Nevin's reanalysis of previous data suggested the slope of extinction was shallower after extended training under a continuous reinforcement schedule (as predicted by behavioral momentum theory). Nevin (1988) also ruled out the alternatives that (a) resistance to extinction is a counterinstance to the general relationship between resistance-to-change and rate of reinforcement, (b) the relationship between resistance-to-change and rate of reinforcement is non-monotonic, and (c) outcomes of resistance-to-change research depend upon whether comparisons involve within-subject designs or multiple schedules. Nevin and Grace (2000) suggested continuous reinforcement results in greater behavioral mass (and thus greater behavioral momentum) than does partial reinforcement; given this, greater persistence of responding in the left-key condition (after reanalysis) in Nevin (1988) might reflect greater behavioral momentum in training with a continuous reinforcement schedule than in training with a partial reinforcement schedule.

Resurgence. Resurgence is the reappearance of a previously extinguished behavior when an alternative behavior reinforced during extinction is also extinguished (e.g., see Cleland, Foster, and Temple, 2000; Mace et al., 2010). Shahan and Sweeney (2011) suggested resurgence can be understood as an extension of how extinction is characterized by behavioral momentum theory, which is that decreases in responding during extinction result from disruptive influences that terminate the contingency between responding and reinforcer. This is not unique to behavioral momentum theory, but behavioral momentum theory does explicitly predict resurgence given the existence of alternative reinforcement (see below). Shahan and Sweeney pointed out that an additional source of reinforcement increases the strength of target behavior (i.e., increases behavioral mass), and consistent with this, Sweeney and Shahan (2013a) found that increased exposure to extinction reduced resurgence. Podlesnik and Shahan (2009, 2010; see also Podlesnik and Kelley, 2014) suggested resurgence occurs if changes in context produced a decrease in disruption associated with extinction (i.e., if there is a decrease in the external force that is reducing momentum [e.g., similar to a decrease in friction, see Nevin, 1988]), and combined with Shahan and Sweeney's observation, it appears that responding can be strengthened while undergoing extinction if an alternative source of reinforcement is introduced (cf. Nevin et al., 1990). Relatedly, the idea that extinction serves as a disruptor suggests extinction might be a type of "behavioral friction" (see Nevin, 1988, cf. representational friction in Hubbard, 1995, 1998), and if this friction is increased or decreased, behavioral momentum is decreased or increased, respectively.

Context

Given that most of the studies on behavioral momentum involve laboratory studies of animal behavior or applied behavioral interventions in humans, it is not surprising that many studies focus on the context of the behavior of interest. Characteristics of the context considered here include (a) reinforcement schedule, (b) whether a previously completed task typically exhibited a high or low level of compliance, (c) reinforcer quality, and (d) the presence of alternative reinforcement.

Reinforcement schedule. Much of the research in behavioral momentum literature involved presentation of multiple reinforcement schedules. Nevin et al. (1983) conditioned pigeons to peck when a green key or a red key was illuminated, and reinforcement for each key was on a different variable interval schedule; the schedule with shorter intervals was always associated with the red key. Food was presented during a subsequent dark-key period, and extinction sessions with illuminated keys were then presented. Responding during dark-key periods declined; decreases were greater for the green-key than for the red-key, and this difference increased with larger differences between green-key and red-key reinforcement rates. A similar pattern occurred during extinction. Estimated ratios of behavioral masses in the green-key and red-key conditions were calculated and increased with increases in the ratio of baseline reinforcement rates. Dark-key periods and extinction each resulted in an apparent decrease in behavioral mass; however, the two methods resulted in differing estimates of the decrease. In dark key periods, the relationship between the ratio of behavioral masses and the ratio of reinforcement rates was a power function with an exponent of approximately 0.7, but in extinction, the relationship between the ratio of behavioral masses and the ratio of reinforcement rates was less clearly related to reinforcement rate ratios (cf. Nevin, 1988).

Cohen, Riley, and Weigle (1993) reported resistance to change was related to reinforcement rate for multiple schedules but not for simple schedules (see also Nevin, 2012). Cohen (1998) noted that stimulus–reinforcer relationships varied between simple schedules and multiple schedules. Given that behavioral momentum theory emphasizes the role of stimulus–reinforcer relationships (Nevin, 1992, 2012; Nevin et al., 1990), such differences could limit the range of applicability of the notion of behavioral momentum. Cohen (1998) measured resistance to change by prefeeding and by extinction for behaviors learned under different variable interval schedules (see also Cohen et al., 1993), and he varied whether these schedules were implemented successively, on alternating days, or as multiple schedules within the same session. The results suggested different reinforcement rates must be compared within the same session or in alternating sessions in order to produce data consistent with behavioral momentum (cf. effects of latency from prior compliance with high probability requests to low probability requests, Mace, Hock, Lalli, West, Belfiore, Pinter, and Brown, 1988). Also, behavioral momentum might be much longer lasting with simple schedules (e.g., Nevin, 1996). Interestingly, the apparently stronger effect of behavioral momentum with multiple schedules (cf. Podlesnik, Thrailkill, and Shahan, 2012) appears consistent with the larger representational momentum that is observed with divided attention than with selective attention (cf. Hayes and Freyd, 2002).

A consistent finding within behavioral momentum literature (e.g., Nevin and Grace, 2005; Nevin et al., 1983; Podlesnik, Bai, and Elliffe, 2012; Podlesnik and

Shahan, 2009, 2010; Podlesnik, Thrailkill, and Shahan, 2012; Sweeney and Shahan, 2013b) is that learning under a schedule that provides more reinforcement per unit of time is more resistant to change than is learning under a schedule that provides less reinforcement per unit of time. This pattern occurs regardless of baseline response rates (Nevin, 1992), and so is consistent with the idea that baseline responding (initial mass) might be independent of response rate (initial velocity). Indeed, just as physical velocity and physical mass are conceptually independent in Newtonian physics, Nevin (1992) argued that steady-state response rate (i.e., behavioral velocity) and resistance to change (i.e., behavioral mass) are conceptually independent. Nevin (1992) examined parameters regarding resistance to change, and as noted earlier, he concluded that response rate depends upon response–reinforcer (operant) contingencies and resistance to change depends upon stimulus–reinforcer (Pavlovian) contingencies (see also Podlesnik and Shahan, 2008). Relatedly, Cohen (1998) observed that experiments reporting evidence consistent or inconsistent with behavioral momentum generally involved learning schedules with higher or lower reinforcement rates, respectively. Thus, behavioral momentum for a newly-learned behavior might be relatively weak or fragile, and so more easily disrupted or masked by other variables or by variance.

Effects of behavioral momentum can last for days, weeks, or perhaps longer. Consistent with the idea of longer time-scales, behavioral momentum has been suggested to provide a useful framework with which to explain some historical events. Nevin (1996) analyzed the occurrence of interstate wars from 1495 to 1990; he found that the proportion of wars initiated by a given nation increased with successive wins and decreased with successive losses, and that the latency to initiate a war was shorter after a win than after a loss. Pulido and López (2010) examined strategies of Admiral Bill Halsey in the Battle of Leyte Gulf and of General Maurice Gamelin in the Battle of France (both during World War II), and they suggested that consequences of previous military experiences shaped the subsequent strategies and military outcomes. More specifically, positive outcomes of a specific strategy lead to a type of momentum in which that strategy will continue to be used, even if changes in circumstances suggest a different strategy might be more optimal or appropriate (but even so, continuation of a specific strategy given previous positive outcomes for that strategy is not unique to theories involving behavioral momentum). Along these lines, behavioral momentum in war appears similar to psychological momentum in competitive sport (cf., perception of a hot-hand effect discussed in Part II). More broadly, such a characterization suggests behavioral momentum might also offer a potential account of mechanization of thought and the Einstellung effect (e.g., see Luchins and Luchins, 1959).

Compliance on previous tasks. One way in which context influences behavioral momentum is if a preceding task involves a high probability of response or compliance or a low probability of response or compliance. Ardoin, Martens, and Wolfe (1999) presented second-grade students with requests that were more likely to result in compliance (i.e., high probability requests) followed by requests that were less likely to result in compliance (i.e., low probability requests). Presentation of a high probability request prior to presentation of a low probability request increased the probability of compliance with the low probability request (see also Ducharme and Worling, 1994). Belfiore, Lee, Scheeler, and Klein (2002) presented developmentally delayed ten-year old children with ten multi-digit multiplication problems to be solved (which had a low probability of compliance). Multi-digit problems (a) were preceded by three single-digit multiplication problems to be solved (which had a high probability of compliance) or (b) contained five problems that were crossed out (i.e., did not have to be solved and could have functioned as negative reinforcement). Both interventions similarly decreased latency to begin the next problem (see also Lee, Belfiore, Scheeler, Hua, and Smith, 2004). Belfiore et al. suggested behavioral momentum established by previous high probability compliance tasks might be more effective in changing subsequent behavior than would focusing on consequences of non-compliant behavior.

Vostal and Lee (2011) reported that reading an easy paragraph (a high probability of compliance) led to decreases in latency to begin reading a difficult paragraph (a low probability of compliance) and to more accurate pronunciation of the first ten words of the difficult paragraph in adolescents. Burns, Ardoin, Parker, Hodgson, Klingbeil, and Scholin (2009) placed easier words at the beginning of a reading list or interspersed easy words throughout the list, and fourth-grade children who received the easy words at the beginning of the list (a high compliance condition) read more total words than did students who received easy words interspersed throughout the list. Kelly and Holloway (2015) used compliance with high probability requests as a tool to improve verbal fluency of low probability tacts in children (three to 4 years old) with autism spectrum disorder. Lee, Belfiore, Ferko, Hua, Carranza, and Hildebrand (2006) reported the latency from completion of a high probability response to initiation of a subsequent low probability response was shorter than the latency from completion of a low probability response to initiation of a subsequent high probability response in normally developing six year olds and in learning disabled fifth graders (see also Wehby and Hollahan, 2000). Belfiore, Basile, and Lee (2008) reported compliance with prior high probability requests increased compliance with subsequent low probability requests in a seven-year old with moderate retardation and Down syndrome.

Reinforcer quality. Mace, Mauro, Boyajian, and Eckert (1997) noted that reinforcers in Mace et al. (1988) involved verbal praise, and Mace et al. (1997) hypothesized that compliance with a subsequent low probability request might be enhanced if reinforcer quality for previous high probability requests was increased. In experiments with developmentally disabled adolescents, Mace et al. (1997) presented food (a higher quality reinforcer) or verbal praise (a lower quality reinforcer) following compliance with high probability requests, and compliance on a subsequent low probability request was enhanced if higher quality reinforcers had been previously presented. If multiple low probability requests were given after compliance with high probability requests, then probability of compliance declined as the number of low probability requests increased, and resistance to change across low probability requests was greater if a higher quality reinforcer had been previously presented. However, it is not clear whether the decline in compliance reflected the number of requests or the time elapsed since high probability requests ended, as Mace et al. (1988) reported compliance on a low probability request decreased if latency since compliance with high probability requests increased (cf. temporal separation in Cohen, 1998). Also, Mace et al. (1997) trained rats on multiple variable interval schedules in which sucrose (a higher quality reinforcer) or citric acid (a lower quality reinforcer) was presented, and they found that subsequent resistance to extinction was greater after presentation of a higher quality reinforcer.

Alternative reinforcement. A consistent finding within behavioral momentum literature is that increases in reinforcement that are not related to responding nonetheless increase resistance to extinction (e.g., Nevin et al., 1990; Podlesnik and Shahan, 2009, 2010). Nevin et al. (1990) reinforced a target response at different rates in different schedules, and additional reinforcers were presented noncontingently or contingent upon a different (alternative) concurrent response. Adding response-independent food (i.e., extra reinforcement) to a variable interval schedule decreased the rate of responding to the stimulus and increased resistance of the target response to change (i.e., to extinction). Such additional food (reinforcement) could be considered as increasing behavioral mass (and thus increasing behavioral momentum). Consistent with this, Mace et al. (2010) reported that problem behaviors in children with developmental disorders decreased more rapidly and to a lower level if treatment included differential reinforcement of alternative behavior (see also Podlesnik, Bai, and Elliffe, 2012). However, although differential reinforcement of desirable behaviors generally decreases rates of problem behaviors, it also increases resistance to extinction of those problem behaviors (cf. Ahearn, Clark, Gardenier, Chung, and Dube, 2003; Dube et al., 2009). Additionally, effectiveness of alternative reinforcement is enhanced if the alternative response is trained in a separate context before being combined with the target context (Podlesnik, Bai, and Elliffe, 2012).

Observer

Given the origin of behavioral momentum theory in learning literature, there has been relatively little investigation of the effects of the observer (e.g., individual differences) on behavioral momentum.[2] Characteristics of the observer considered here include (a) attention and (b) psychopathology.

Attention. Dube, McIlvane, Mazzitelli, and McNamara (2003; see also Dube and McIlvane, 2001) had mentally-challenged participants complete discrimination

[2]In discussion of behavioral momentum and psychological momentum, the term "target" refers to a specific behavior that is exhibited by an organism. Presumably an organism that exhibited a target behavior could in many instances observe itself exhibiting that behavior, and so the term "observer" can refer either to an organism that exhibits the target behavior or to an organism that does not exhibit the target behavior.

tasks involving selective attention, and the reinforcer was snack food. Participants who received higher rates of reinforcement exhibited larger behavioral momentum. Podlesnik, Thrailkill, and Shahan (2012) presented pigeons with center key stimuli consisting of lines that varied in color (blue, green) and in orientation (horizontal, vertical). After the stimulus vanished, side keys presented each of the two colors or each of the two orientations. Choosing the side key corresponding to the color or orientation that appeared in the preceding stimulus resulted in food presentation on a predetermined schedule. As the initial stimulus always included a color and an orientation, and it was not possible to know in advance which dimension would need to be remembered, Podlesnik et al. considered this task to involve divided attention. Pigeons that received a higher rate of reinforcement exhibited greater resistance to disruption due to presession feeding or to extinction, and this is consistent with behavioral momentum. Given the existence of behavioral momentum with selective or divided attention, it could be informative to examine resistance to disruption in divided attention relative to resistance to disruption in selective attention (e.g., representational momentum literature would predict an increase in behavioral momentum with divided attention). Also, Nevin, Davison, and Shahan (2005) proposed a theory of attention based on reinforcement rate, which they suggested paralleled behavioral momentum theory.

Psychopathology. Behavioral momentum theory has been used in treatment of problem behaviors (and in establishing new desirable behaviors) in humans diagnosed with developmental or learning disorders. Mace, Lalli, Shea, Lalli, West, Roberts, and Nevin (1990) examined behavioral momentum in mentally-challenged adults in a group home; responding involved sorting different types of dinnerware, and the distractor was a video. As predicted by behavioral momentum theory, responding accompanied by a higher rate of reinforcement was more resistant to disruption (see also Mace et al., 2010). Mace et al. (1988; see also Mace and Belfiore, 1990) found that presenting a mentally-challenged patient with requests that had a high probability of being obeyed established a momentum of compliance that increased the probability the patient would obey a subsequent request that previously had a low probability of being obeyed. Ahearn et al. (2003) reported that three children (aged four to 9) diagnosed with autism spectrum disorder and who displayed vocal or manual stereotypy exhibited more resistance to change following access to preferred stimuli. As discussed by Dube et al. (2009), even though stereotypies decreased during noncontingent reinforcement, stereotypies were more difficult to extinguish after noncontingent reinforcement was withdrawn; this is consistent with behavioral momentum but not consistent with a partial reinforcement extinction effect.

Many studies of behavioral momentum involving psychopathology sought to improve academic performance in children diagnosed with developmental or learning disorders (e.g., Belfiore, Lee, Vargas, and Skinner, 1997; Belfiore et al., 2002, 2008; Burns et al., 2009; Kelly and Holloway, 2015; Lee et al., 2004, 2006; Vostal and Lee, 2011; Wehby and Hollahan, 2000), and these studies usually found that behavioral momentum induced by successful completion of a task with a high probability of compliance improved performance on academic tasks that had an initially low probability of compliance (see also Lee, 2006). Relatedly, Parry–Cruwys, Neal, Ahearn, Wheeler, Premchander, Loeb, and Dube (2011) reinforced developmentally delayed children (four to 13 years old) for completing regularly scheduled academic or leisure tasks, and consistent with behavioral momentum theory, behavior with a higher reinforcement rate was more resistant to disruption. Strand (2000) suggested behavioral momentum provides a useful perspective on child conduct disorder, and Romano and Roll (2000) suggested techniques to increase behavioral momentum are useful in increasing compliance behaviors in youth with developmental disorders. Pritchard, Hoerger, Mace, Penney, and Harris (2014) suggested animal models of relapse based on behavioral momentum (e.g., Podlesnik and Shahan, 2009, 2010) can serve as models of treatment relapse in humans.

Part II: Psychological Momentum

Psychological momentum has been conceptualized as a power or force that changes interpersonal perceptions and influences mental or physical performance (Iso–Ahola and Mobily, 1980), as a bidirectional concept that affects the probability of winning or losing as a function of the outcome of the preceding event (Adler, 1981), and most recently as a psychological phenomenon that mediates or moderates performance (Iso–Ahola and Dotson, 2014, 2015). More specifically, the notion of positive psychological momentum suggests that current success or victory increases the likelihood of subsequent success or victory, whereas the notion of negative psychological momentum suggests that current failure or defeat increases the likelihood of subsequent failure or defeat (but see Cornelius, Silva, Conroy, and Petersen, 1997). Although many researchers accept these characterizations, there have been calls for a redefinition of psychological momentum that is based on a closer study of the relevant phenomenology (e.g., Crust and Nesti, 2006). Several theories of psychological momentum have been proposed (e.g., Cornelius et al. 1997; Iso–Ahola and Dotson, 2014; Markman and Guenther, 2007; Taylor and Demick, 1994; Vallerand et al., 1988); a complete review of this literature is beyond the scope of this article, but a selective review of psychological momentum that focuses on primary findings and highlights similarities to behavioral momentum is presented.

Target

As in studies of behavioral momentum, the target in studies of psychological momentum is a specific behavior of an organism (and in studies of psychological momentum, the organism is usually human). Characteristics of the target considered here include (a) valence, (b) direction, (c) duration, (d) mass, (e) task, and (f) prior probability.

Valence. Psychological momentum can be described as positive or as negative. Even so, in positive psychological momentum and in negative psychological momentum, the direction of momentum always involves forward extrapolation in the current direction of motion (toward success or failure, respectively); therefore, distinguishing between positive psychological momentum and negative psychological momentum does not make psychological momentum inconsistent with other types of momentum-like effects that do not involve such a distinction. Silva, Hardy, and Crace (1988) considered the possibility of behaviors in the direction opposite to psychological momentum. In *positive inhibition*, success increases the probability of subsequent failure (e.g., a team that is leading grows complacent and loses), and in *negative facilitation*, failure increases the probability of subsequent success (e.g., a team that is trailing becomes "fired up" and more motivated to succeed). Silva et al. reported that positive psychological momentum and negative psychological momentum occurred more often than did positive inhibition and negative facilitation, and so behavior consistent with behavioral momentum occurred more often than did behavior inconsistent with behavioral momentum. Stanimirovic and Hanrahan (2004) reported performance did not improve with increases in positive psychological momentum, but performance did improve with increases in negative psychological momentum (i.e., negative facilitation, cf. Perreault, Vallerand, Montgomery, and Provencher, 1998).

Direction. Gernigon, Briki, and Eykens (2010) examined how changes in apparent direction influenced psychological momentum. Participants were regional level table-tennis players asked to empathize with a player in a video of an important competitive table-tennis match. Over the course of the video, the score gap increased or decreased. Variations in cognitive anxiety and in somatic anxiety reported by participants were suggested to reflect psychological momentum such that linear increases in positive psychological momentum occurred if the video suggested moving from likely defeat to likely victory, but nonlinear increases in negative psychological momentum occurred if the video suggested moving from likely victory to likely defeat. Gernigon et al. also reported psychological momentum was stronger with a negative direction of motion than with a positive direction of motion (cf. Stanimirovic and Hanrahan, 2004). Similarly, ratings of mastery-avoidance goals (which focus on avoiding mistakes) exhibited a nonlinear decrease as likelihood of victory increased and a nonlinear increase as likelihood of defeat increased, a pattern that Gernigon et al. interpreted as consistent with negative hysteresis (see also Briki, Doron, Markman, den Hartigh, and Gernigon, 2014). Gernigon et al. suggested their data illustrated the dynamic nature of psychological momentum (see Part III). However, the ways in which cognitive anxiety, somatic anxiety, and mastery-avoidance goals are related to psychological momentum are not clear.

Duration. Hunt, Rietschel, Hatfield and Iso–Ahola (2013) found that winners of a shooting competition reported greater confidence than did losers, and this difference increased with increases in the duration of success. Iso–Ahola and Dotson

(2014) suggested enhanced success or even neutral performance can maintain psychological momentum, but that psychological momentum can be terminated by (a) interrupting performance (e.g., a time-out in a basketball game; Mace, Lalli, Shea, and Nevin, 1992), and (b) an individual's unsuccessful performance or an opponent's successful performance (e.g., falling behind in a virtual cycling contest; Briki, den Hartigh, Markman, and Gernigon, 2014). Hamberger and Iso–Ahola (2004) suggested psychological momentum is relatively short-lived, but that the longer a person can maintain positive psychological momentum, the more likely success, or victory, become. Consistent with this, single or isolated successes within a longer contest might not be sufficient to produce a perception of psychological momentum unless such instances are particularly intense (Iso–Ahola and Dotson, 2014). Although psychological momentum is usually considered as occurring within a single performance (e.g., an individual game), psychological momentum has been suggested to also occur across performances (e.g., multiple games in a tournament), but this suggestion has not yet been empirically examined. Interestingly, an extension across multiple performances is consistent with the notion that psychological momentum emphasizes continuation across time rather than across space (see Hubbard, in press).

Mass. Markman and Guenther (2007) posited that psychological momentum is sensitive to naïve physics beliefs, and they focused on naïve physics beliefs regarding mass. In one experiment, participants read a description of a basketball game in which one team, East Midland, defeated a team that was or was not a major rival. Just as increases in the size of a physical object leads to perception of greater mass, Markman and Guenther found a goal that is perceived as more important or valuable connotes a greater mass. Thus, the presence of a major rivalry was predicted to increase the behavioral mass of East Midland's victory, and consistent with this, participants predicted a greater likelihood that East Midland would win their next game if the team East Midland defeated was a major rival. Interestingly, naïve physics beliefs regarding mass influence other momentum-like effects (e.g., beliefs regarding impetus influence representational momentum, e.g., Hubbard, 2013; Hubbard and Ruppel, 2002; Kozhevnikov and Hegarty, 2001). Nevin (1988) pointed out that an absolute scale for behavioral mass cannot exist (in part because the units in which behavioral mass is specified vary across situations and experiments), and he suggested behavioral mass reflected differences between conditions rather than absolute values. A similar caveat should also apply to psychological mass (e.g., in Markman and Guenther's experiment, the increase in behavioral mass if a major rival was defeated was due to the greater importance of defeating a major rival than of defeating a non-rival).

Task. The majority of studies on psychological momentum involved athletic performance or competition. However, Markman and Guenther (2007) proposed psychological momentum should occur in domains other than sport (see also Iso–Ahola and Dotson, 2014). In one of Markman and Guenther's experiments, participants read about an individual, Jane, attempting to complete two tasks (cleaning an apartment, writing a paper) by a self-imposed deadline. In one version, Jane was described as making steady progress on the first task, and in another version, Jane was described as experiencing momentum while completing the first task. Participants who read the latter version judged Jane had more momentum going into the second task and was more likely to complete the second task by the deadline. Also, participants indicated Jane would have more difficulty finishing the second task after an interruption at the end of the first task if momentum had been experienced in the first task. Markman and Guenther conjected that psychological momentum might be perceived as hard to lose once it is gained but harder to regain once it is lost. Interestingly, tasks used by Markman and Guenther seem similar to domestic and academic tasks in studies of behavioral momentum (e.g., Belfiore et al., 2002; Dube et al., 2009; Lee et al., 2004; Mace et al., 1990), and this suggests a possible connection between behavioral momentum and psychological momentum. Consistent with this latter point, athletic performance and competition have been used as stimuli in studies of behavioral momentum (e.g., Roane, 2011).

Prior probability. One of the clearest examples of psychological momentum is belief in the "hot hand" in basketball. If a player has made several baskets in a row, he or she is considered to have a "hot hand," and the generally accepted strategy is that a player with a hot hand should continue taking shots. Gilovich, Vallone, and Tversky (1985) compared subjective perception of randomness in basketball shooting with actual performance data. Existence of a hot hand effect was not supported statistically, and examples of a perceived hot hand were not significantly different from scoring streaks predicted by a binomial model with a constant hit rate (i.e., that assumed no dependency between previous success and subsequent success). Vergin (2000) reported that winning streaks over a full season of play by major league baseball teams and by national basketball association teams did not differ from what would be expected if the outcome of a given game was independent of the outcome of the previous game, and he suggested that undue importance was placed on momentum as a causal factor in determining the outcomes of games. Similarly, O'Donoghue and Brown (2009) reported the distribution of service points in elite men's tennis did not differ from chance. The lack of statistical significance of streaks led Gilovich et al. (p. 313) to suggest that psychological momentum is a "powerful and widely shared cognitive illusion" (cf. Roediger's, 1996, suggestion that representational momentum is a memory illusion).

The claims of Gilovich et al. (1985) and others that the hot hand effect does not exist have been challenged. In a detailed review, Bar-Eli, Avugos, and Raab (2006) reported the majority of empirical evidence does not support the existence of a hot hand effect, but the potential existence of a hot hand effect could not be ruled out. Wardrop (1995) reanalyzed the data of Gilovich et al. and suggested that collapsing data over individual players could lead to perception of a hot hand effect. Iso–Ahola and Dotson (2014) contended the hot hand effect exists but is difficult to detect because it is relatively infrequent. Most investigations of the hot hand effect have involved team sports such as basketball and baseball, and Iso–Ahola and Dotson suggested hot hand effects might be more frequent in individual sports (e.g., billiards, tennis; Bar-Eli et al., 2006) than in team sports, if opponents were less able to employ countermeasures (e.g., volleyball; Raab, Gula, and Gigerenzer, 2012), or if performance trials were uniform (e.g., bowling; Yaari and David, 2012). Although investigations of the hot hand effect have generally focused on athletic or sport performance, Iso–Ahola and Dotson point out that nonathletic versions of a hot hand effect have been reported in gambling (e.g., Arkes, 2011) and financial decision-making (e.g., Hendricks, Patel, and Zeckhauser, 1993). They consider psychological momentum to be a psychological force rather than a statistical effect, and in the case of the hot hand effect, Iso–Ahola and Dotson propose psychological momentum mediates or moderates rather than causes future success (see also Avugos and Bar-Eli, 2015; Iso–Ahola and Dotson, 2015).

Context

Given that many studies of psychological momentum do not involve the level of laboratory or environmental control found in studies involving behavioral momentum, characteristics of the context are not emphasized as much in studies of psychological momentum as in studies of behavioral momentum. Characteristics of the context considered here include (a) cohesion, (b) configuration, and (c) preceding performance.

Cohesion. Adler (1981) suggested increased cohesion creates a climate more favorable for perception of psychological momentum. To examine this, Eisler and Spink (1998) presented volleyball players at a high school level tournament with written scenarios in which their team and their opponent were tied at 13 in the third game of a best-of-three series. Team members also filled out questionnaires assessing team cohesion. Teams with overall higher cohesion generally perceived greater (positive) psychological momentum than did teams with neutral or low cohesion. The extent to which negative psychological momentum might be influenced by cohesion is not yet clear. Relatedly, Stanimirovic and Hanrahan (2004) examined team-efficacy (i.e., belief in team members' ability to perform) in volleyball players, and they reported that successes and failures led to increases and decreases, respectively, in team-efficacy. It could be predicted that increases in team-efficacy might result in larger or more frequent episodes of positive psychological momentum (perhaps related to cohesion), but such an hypothesis has not been tested. Also, it is not clear how cohesion would affect a single individual in a non-team competition (e.g., men's tennis singles), although it could be hypothesized that the range of cohesion might be extended to include coaches, managers, or others involved with the individual.

Configuration. Vallerand et al. (1988) suggested psychological momentum is dependent upon context and not solely dependent upon individual events (e.g., "making three steals in a row in basketball while you are winning by 30 does not greatly affect the PM [psychological momentum] perceived in the situation. However, three steals in a row to tie the score is a different situation" [p. 95]). Vallerand et al. reported more psychological momentum was attributed to a tennis player who came from behind by winning four games to tie the score at 5 than was attributed to that player if he and his opponent alternated wins in that set (see Eisler and Spink, 1998; and Miller and Weinberg, 1991, for similar findings in volleyball), and this suggests scoring streaks are associated with increased positive psychological momentum (i.e., perception of a hot hand effect). As noted by Eisler and Spink (1998), calling a time-out as a way to slow or disrupt an opponent's momentum might be a useful strategy (e.g., Mace et al., 1992, reported the number of points scored by the opposition decreased following a time-out in basketball; however, Wanzek, Houlihan, and Homan, 2012, reported that calling a timeout did not reduce the velocity of a subsequent serve in volleyball). Eisler and Spink suggested psychological momentum was influenced by elapsed time: the longer the temporal interval in which the relevant event occurs, the weaker the psychological momentum (cf. Hamberger and Iso–Ahola, 2004). Consistent with this, Silva et al. (1988) suggested it might be easier to observe psychological momentum in "micro" events (e.g., points and rallies) than in "macro" events (e.g., games and sets).

Preceding performance. Although some studies reported that individuals who won the first game in billiards (Adams, 1995) or the first set in tennis or racquetball (Iso–Ahola and Blanchard, 1986; Iso–Ahola and Mobily, 1980; Silva et al., 1988; Weinberg, Richardson, and Jackson, 1981) were more likely to win the next game or set, other studies did not find such an effect (e.g., Ransom and Weinberg, 1985; Stanimirovic and Hanrahan, 2004). Silva, Cornelius, and Finch (1992) had participants compete in a novel task; although participants reported differences in psychological momentum as a function of whether feedback suggested victory or defeat, there were no differences in performance as a function of reported psychological momentum (cf. Kerick, Iso–Ahola, and Hatfield, 2000). Similarly, Miller and Weinberg (1991) reported that psychological momentum had minimal influence on performance. Perreault et al. (1998) had participants complete a (virtual) bicycle race (on an indoor stationary cycle) while simultaneously viewing a video reported to be of a real-time competitor. If the video suggested participants lost the lead, their reported psychological momentum decreased, and if the video suggested participants came from behind to tie, their reported psychological momentum increased (cf. Briki, den Hartigh, Markman, and Gernigon, 2014). Also, there was a trend for increases in performance (speed of pedaling) if a participant was falling behind (i.e., negative facilitation), and Perreault et al. suggested psychological momentum facilitates performance only if the task requires great effort.

Although preceding performance is often assumed to give rise to psychological momentum, Burke, Edwards, Weigand, and Weinberg (1997) reported that spectators of tennis or basketball matches exhibited surprisingly low agreement

(<25%) regarding the specific events that triggered or terminated psychological momentum (but see Burke, Burke, and Joyner, 1999). Jones and Harwood (2008) interviewed competitive soccer players, and those players identified triggers of psychological momentum involving opponent behaviors and their own confidence. If a player saw an opponent's negative body language or conflict with a teammate, that could give rise to positive psychological momentum, whereas if an opponent was playing well, that could give rise to negative psychological momentum. Also, a high level of confidence could give rise to or be an outcome of positive psychological momentum, whereas a low level of confidence could give rise to or be an outcome of negative psychological momentum. Along these lines, some theories suggest psychological momentum influences subsequent performance (Iso–Ahola and Dotson, 2014; Taylor and Demick, 1994; Vallerand et al., 1988), and this suggests a positive feedback loop (i.e., increases in positive [negative] psychological momentum increases [decreases] performance, which in turn increases positive [negative] psychological momentum). However, other theories (e.g., Cornelius et al., 1997) suggest psychological momentum is solely a consequence of preceding performance and is not a cause of future performance (cf. Miller and Weinberg, 1991; Silva et al., 1992).

Observer

Perhaps the most widely investigated class of variables in studies of psychological momentum involve characteristics of the observer. Characteristics of the observer considered here include (a) sex, (b) affect, (c) whether feedback is received, (d) self-efficacy, (e) ability, and (f) whether the observer has control of the action or outcome.

Sex. Iso–Ahola and Mobily (1980) reported greater positive psychological momentum for male players than for female players in racquetball, and Weinberg et al. (1981; see also Weinberg, Richardson, Jackson, and Yukelson, 1983) reported that in junior and professional tennis, males came from behind to win more often than did females. Silva et al. (1988) examined archival data from three seasons of a Division I collegiate men's tennis team and collegiate women's tennis team, and they found that reports of psychological momentum did not vary as a function of sex. Smission, Burke, Joyner, Munkasy, and Blom (2007) did not find a difference in the number of psychological momentum sequences reported by males or females viewing collegiate basketball games, nor was there a difference in the number of psychological momentum sequences reported in men's or women's games. Mace et al. (1992) had participants view videotapes of men's collegiate basketball games and count the reinforcers, adversities, and favorable responses to adversity. Favorable responses to adversity increased as the number of reinforcers during the preceding three minutes increased, and this appears consistent with behavioral momentum and with psychological momentum. Roane, Kelley, Trosclair, and Hauer (2004) attempted to replicate Mace et al.'s findings with participants who viewed videotapes of women's collegiate basketball games. Roane et al. found a lower overall rate of reinforcement, and whether favorable responses to adversity were related to the amount of preceding reinforcement was not as clear.

Affect. Kerick et al. (2000) examined whether psychological momentum was related to subsequent performance or to changes in affective or electrophysiological responses. They provided false feedback to novice participants engaged in target shooting; additionally, questionnaires regarding affective responses and psychological momentum were administered, and EEG data were collected during performance. Reported (positive) psychological momentum was lower if participants received low feedback scores than if participants received neutral, high, or no feedback scores. Subsequent target shooting performance, affective responses, and left–right asymmetries in the EEG data (recorded from F3 and F4) were not influenced by feedback. Kerick et al. suggested psychological momentum was independent of affective, electrophysiological, and performance effects in novice participants performing a fine motor task. However, this suggestion is not consistent with the multidimensional model of psychological momentum proposed by Taylor and Demick (1994), in which psychological momentum is the output of a chain of processes including affective responding, and in which psychological momentum is associated with affective changes in the same direction as the valence of subsequent psychological momentum.[3] The relationship of affect with psychological momentum is not yet clear and remains a topic for future research.

Feedback. Whether psychological momentum is positive or negative is a function of whether a person is succeeding (winning) or failing (losing), and so feedback regarding performance would appear to be a contributor to the belief in or experience of psychological momentum. Surprisingly, relatively few studies have examined the role of feedback in psychological momentum. In an early set of studies, Feather and colleagues (Feather, 1966, 1968; Feather and Saville, 1967) found a positive effect of feedback on psychological momentum, as participants were more successful in solving subsequent anagrams if they had experienced success in solving previous anagrams. In recent studies, and as noted earlier, feedback suggesting an unsuccessful performance decreased positive psychological momentum but had no impact on actual subsequent performance (Kerick et al., 2000), and feedback

[3]As noted earlier, psychological momentum can have positive or negative valence. The issue of valence makes the relationship of affect and momentum-like effects less straightforward. In general, it might appear that perception of positively-valenced psychological momentum would be more likely to involve positive affect, and perception of negatively-valenced psychological momentum would be more likely to involve negative affect. However, caveats and counterexamples can be hypothesized. It is also possible that an affective response might exhibit a momentum-like effect in the absence of psychological momentum, and such an effect might be consistent with an "affective momentum," in which the intensity of felt emotional experience exhibits momentum-like effects. Indeed, to the extent that facial expression is linked to felt emotion (e.g., Strack, Martin, and Stepper, 1988), previous findings of representational momentum for facial expression (e.g., Yoshikawa and Sato, 2008) would be consistent with the existence of such an affective momentum.

suggesting a participant had lost or regained the lead in a cycling race decreased or increased, respectively, positive psychological momentum (Briki, den Hartigh, Markman, and Gernigon, 2014; Perrault et al. 1998). Iso–Ahola and Dotson (2014) claimed positive or neutral feedback can maintain positive psychological momentum and that attributions based on feedback and performance outcomes play an important role in creating and maintaining psychological momentum. Consistent with this, Iso–Ahola and Dotson also note that success reinforces an individual's perception of himself or herself as a capable performer and motivates for greater achievement, and that this could contribute to perceptions of momentum.

Self-efficacy. Shaw, Dzewaltowski, and McElroy (1992) proposed self-efficacy might account for laypersons' interpretations of psychological momentum. Self-efficacy involves a belief that one can successfully perform the behaviors necessary to achieve a desired outcome (Bandura, 1977, 1990). Individuals who experience success should experience an increase in self-efficacy, thus increasing their efforts if future performances appear to be falling short, and thereby increasing the probability of future success. Similarly, individuals who experience failure would experience a decrease in self-efficacy, thus decreasing their efforts if future performances appear to be falling short, and thereby increasing the probability of future failure (cf. effects of team-efficacy in Stanimirovic and Hanrahan, 2004). Shaw et al. paired male undergraduate participants with skilled confederates in a basketball free-throw shooting contest, and participants were randomly assigned to a success condition or a failure condition. After each set of ten shots by a participant and ten shots by the confederate, that participant filled out questionnaires assessing his own psychological momentum and his own self-efficacy. In the success condition, positive psychological momentum and self-efficacy each increased over time but were not significantly correlated. However, in the failure condition, (positive) psychological momentum and self-efficacy decreased over time and were significantly correlated. Shaw et al. concluded that psychological momentum and self-efficacy were different constructs and depended upon different antecedents.

Ability. A player or team that wins the first game or set might be more likely to win the second game or set (or the match) because of having more ability and not because of having psychological momentum. Studies of psychological momentum have attempted to control for differences in ability by creating a novel task (e.g., Silva et al., 1992), pairing experimental participants with a high-ability confederate and varying the confederate's performance (e.g., Shaw et al. 1992), providing false feedback (e.g., Kerick et al., 2000), or restricting the sample to elite performers (e.g., Ransom and Weinberg, 1985). Iso–Ahola and Blanchard (1986) reported racquetball players who won the first set rated themselves as more likely to win the second set and as having more ability than did players who lost the first set. Effects of reported psychological momentum appeared as large in expert players as in novice players, although differences in ability across expert players would presumably have been less than differences in ability across novice players. Gayton, Very, and Hearns (1993) reported professional hockey teams in the Stanley Cup finals that outscored their opponent during the first period were more likely to win the game, and there would presumably be minimal differences in ability at this championship level. Consistent with this, Miller and Weinberg (1991) reported low-skill volleyball players predicted that psychological momentum would have larger effects on game outcome than did high-skill volleyball players (although perceived psychological momentum was actually unrelated to game outcome).

Control. The antecedents–consequences model of psychological momentum of Vallerand et al. (1988) suggests that whether individuals have control of the action or outcome is a key variable in determining whether psychological momentum is perceived. One implication of this is that spectators of athletic events, who have less control over the action, should perceive psychological momentum less strongly than do athletes, who have more control over the action (see also Burke et al., 1997); however, comparisons of psychological momentum simultaneously experienced by spectators and by athletes and for the same stimuli have not been reported, although Briki, Doron, Markman, den Hartigh, and Gernigon (2014) reported that virtual actors who imagined themselves playing table tennis reported lower psychological momentum than did participants who imagined themselves observing table tennis. Curiously, the relationship of psychological momentum to standard locus-of-control measures has not been reported, although Smission et al. (2007) did compare spectators' perceptions of psychological momentum in collegiate basketball games with those spectators' responses on the Belief in Personal Control Scale (Berrenberg, 1987). Smission et al. found that the number of psychological momentum sequences perceived and external control were negatively correlated; however, the number of psychological momentum sequences perceived did not significantly correlate with exaggerated internal control or with god-mediated control.

Part III: Comparison and Representation

Parts I and II reviewed findings on behavioral momentum and psychological momentum, respectively. Part III summarizes similarities and differences of behavioral momentum and psychological momentum, suggests behavioral momentum and psychological momentum fulfill the criteria for dynamic representation, compares properties of behavioral momentum and psychological momentum with properties of dynamic representation, suggests advantages of considering behavioral momentum and psychological momentum as based on or involving dynamic representation, and considers possible relationships of behavioral momentum and psychological momentum.

Similarities and Differences

Studies of behavioral momentum arose out of learning theory and behavior analysis and generally involve laboratory experiments with nonhuman animals or behavioral modification in humans with developmental or learning disorders, whereas studies of psychological momentum arose out of social psychology and sports psychology and generally involve experiments with stimuli or settings from everyday life and normative human populations. Even so, a few studies of psychological momentum involving laboratory settings (e.g., Briki, den Hartigh, Markman, and Gernigon 2014; Kerick et al., 2000; Perreault et al., 1998), and a few studies of behavioral momentum involving everyday stimuli and settings (e.g., Mace et al. 1992; Pritchard et al., 2014; Roane, 2011), have been reported. However, differences in methodology and in nomenclature between domains typically considered in studies of behavioral momentum and domains typically considered in studies of psychological momentum can obscure potential similarities. Also, at least some potential differences might reflect the lack of investigation in a specific domain rather than an actual difference between behavioral momentum and psychological momentum (e.g., valence is important for psychological momentum but not yet investigated for behavioral momentum, and an influence of valence on behavioral momentum seems plausible, e.g., effects of valence and predispositions on approach/avoidance behaviors, Chen and Bargh, 1999). Given this, comparisons of behavioral momentum and psychological momentum have considerable heuristic value in generating new hypotheses and applications.

Numerous similarities of behavioral momentum and psychological momentum are apparent, and these are listed in Table 1. Behavioral momentum (e.g., Nevin, 1988) and psychological momentum (e.g., Mace et al., 1992) involve continuation of previously reinforced behaviors. Behavioral momentum in compliance (e.g., Mace et al., 1988), in which low probability events are more likely if success (compliance) is previously established, appears similar to psychological momentum in perception of a hot hand effect (e.g., Iso–Ahola and Dotson, 2014). Behavioral momentum (e.g., Nevin, 1988; Nevin and Grace, 2000) and psychological momentum (e.g., Markman and Guenther, 2007) are increased (i.e., less susceptible to disruption) if reinforcement rate is increased. Behavioral momentum (e.g., Nevin and Shahan, 2011) and psychological momentum (e.g., Eisler and Spink, 1998; Markman and Guenther, 2007) can be disrupted if the contingency between the response (i.e., the task) and the reinforcer is interrupted or delayed. Behavioral momentum (e.g., Mace et al., 1988; Parry–Cruwys et al., 2011) and psychological momentum (e.g., Markman and Guenther, 2007) can facilitate desired behaviors. Behavioral momentum (e.g., Pulido and López, 2010) and psychological momentum (e.g., Gilovich et al., 1985) can result in continued use of a previously successful strategy even if such a strategy is no longer optimal or appropriate. Behavioral momentum (e.g., Mace et al., 1992) and psychological momentum (e.g., Eisler and Spink, 1998) have been used to understand athletic performance. Behavioral momentum (e.g., Mace et al., 1997) and psychological momentum (e.g., Markman and Guenther, 2007) are increased with increases in reinforcer quality.

Table 1

Similarities of Behavioral Momentum and Psychological Momentum

Behavioral Momentum	Psychological Momentum
Involves continuation of previously reinforced behaviors (Nevin, 1988)	Involves continuation of previously reinforced behaviors (Mace et al., 1992)
Low probability behaviors are more likely if success was previously established (e.g., compliance, Mace et al., 1988)	Low probability behaviors are (perceived as) more likely if success was previously established (e.g., hot-hand effect, Iso–Ahola and Dotson, 1985)
Increased if reinforcement rate is increased (Nevin and Grace, 2000)	Increased if reinforcement rate is increased (Markman and Guenther, 2007)
Disrupted if contingency between response and reinforcer is disrupted (Nevin and Shahan, 2011)	Disrupted if the task is interrupted (Briki, Doron, Markman, den Hartigh, and Gernigon, 2014; Eisler and Spink, 1998; Markman and Guenther, 2007)
Can facilitate accomplishing desired behaviors (Mace et al., 1988; Parry–Cruwys et al., 2011)	Can facilitate accomplishing desired behaviors (Markman and Guenther, 2007)
Can result in continued use of a previously successful strategy even if that strategy is no longer optimal (Pulido and López, 2010)	Can result in continued use of a previously successful strategy even if that strategy is no longer optimal (Gilovich et al., 1985)
Has been applied to understanding athletic performance (Mace et al., 1992)	Has been applied to understanding athletic performance (Eisler and Spink, 1998; Gilovich et al., 1985)
Increased with increases in reinforcer quality (Mace et al., 1997)	Increased with increases in reinforcer quality (e.g., importance of the previous behavior, Markman and Guenther, 2007)
Appears to involve dynamic representation (Part III of this paper)	Appears to involve dynamic representation (Part III of this paper)

A potentially stronger argument regarding the similarity of behavioral momentum and psychological momentum can be made, however. The same environment-based interpretation of behavioral momentum is equally applicable to psychological momentum (i.e., the presence and strength of a momentum-like effect is determined by context-specific reinforcement for performance). Behavioral momentum and psychological momentum each reflect effects of environmental contingencies on the individual. Along these lines, negative facilitation parallels an increase in motivation to escape an aversive stimulus, and positive inhibition parallels a reinforcer losing its effectiveness as a result of satiation. The notion of a momentum-like effect that covaries with performance in a given context is applicable to overt processes (e.g., behavioral momentum) and to covert processes (e.g., psychological momentum). In this light, behavioral momentum and psychological momentum are more than similar; they are virtually the same momentum-like effect, with the modifier "behavioral" applied when describing an observed behavior and the modifier "psychological" applied when describing a reported subjective experience. Of course, humans are capable of more diverse, subtle, and sophisticated behaviors and psychological states than are many nonhuman animals, and so subjective aspects of psychological momentum in humans need not necessarily be attributed to examples of behavioral momentum in nonhuman animals.

Criteria of Dynamic Representation

Behavioral momentum and psychological momentum involve expectations regarding upcoming action or behavior. These expectations are based on a momentum metaphor, and target actions or behaviors are represented (at least in part) as involving or reflecting forces (cf. representation of forces in Freyd, Pantzer, and Cheng, 1988; Leyton, 1989, 1992). This implies that representations of those actions or behaviors are dynamic or contain dynamic information (cf. Briki, den Hartigh, Markman, and Gernigon, 2014). Freyd (1987) suggested another momentum-like effect, representational momentum, involved dynamic representation, and given this, it is useful to consider whether Freyd's notions of dynamic representation can be adapted or expanded to include behavioral momentum and psychological momentum. Although time-scale of change in dynamic representation in Freyd's framework is much faster than time-scales of change in behavioral momentum and psychological momentum, it is not clear that a dynamic framework is necessarily tied to a specific time-scale or temporal range, and so the notion of dynamic representation can perhaps be expanded to include the longer time-scales of behavioral momentum and psychological momentum. Along these lines, a potential neural architecture of an anticipatory system capable of operating at multiple time-scales is discussed in Jordan (2013), and such a system is consistent with the hypothesis that different momentum-like effects reflect the same dynamic processes or systems.

Freyd (1987) suggested that if a mental representation was dynamic, then that representation intrinsically and necessarily represented time (i.e., included temporal information). For time to be an intrinsic aspect of the representation, temporal information must be directional (i.e., moving in only one direction) and continuous (i.e., between any two points in time, a third point can be identified).[4] The directionality of behavioral momentum and psychological momentum is

[4]Although it can be debated whether time is continuous at scales other that those experienced in daily life (e.g., time might be discrete at the quantum level), time as experienced in daily life appears continuous. Analogously, space is experienced as Euclidean in daily life, even though space is considered to be curved and warped at the astronomical level or at the quantum level. In considering the importance of continuity of time and space for dynamic representation, the important point is whether time and space are perceived and experienced as continuous (and thus presumably represented as continuous) and not whether time and space are actually continuous.

demonstrated in that past experience influences future behavior but future behavior does not influence past experience. The continuity of behavioral momentum and psychological momentum is demonstrated in the existence of an apparently continuous range of time-scales (rather than just a few discrete time-scales) in which momentum-like effects occur (cf. Jordan, 2013, who proposed a "multiscale effect control" that pre-specifies [i.e., predicts] perception and action at multiple time-scales). Also, time is clearly a necessary aspect of behavioral momentum and psychological momentum. If temporal information were not present, then all information would be represented as simultaneous (i.e., not temporally ordered), and this would eliminate critical information (e.g., conditioning [or attributions of causality] would not be possible, as information regarding conditioned and unconditioned stimuli and responses [or cause and effect more generally] could not be separated). Thus, behavioral momentum and psychological momentum fulfill Freyd's criteria regarding intrinsic and necessary inclusion of temporal information.

Behavioral Momentum, Psychological Momentum, and Properties of Dynamic Representation

If behavioral momentum and psychological momentum involve dynamic representation, then these two momentum-like effects should exhibit properties similar to those attributed to dynamic representation. Freyd (1987) proposed several candidate properties for dynamic representation, and these are listed in Table 2. Two of Freyd's proposed properties are based on the short time-scale of representational momentum, and these suggest that changes in dynamic representation occur very rapidly and increase over short retention intervals. However, if the point of being dynamic is that change occurs over time, then it does not seem necessary to require that such change occur within a specific time-scale. Thus, these two properties might be too narrowly defined (being based on a single form of momentum-like effect with a short time-scale). Even so, findings that psychological momentum is relatively short-lived (Hamberger and Iso–Ahola, 2004) and decreases with increases in the temporal interval in which it occurs (Eisler and Spink, 1998) are consistent with the decline of representational momentum after an early initial peak (Freyd and Johnson, 1987). It is unclear whether a third suggested property, that changes in dynamic representations are not due to guessing, applies to behavioral momentum and to psychological momentum. Whether nonhuman animals in experiments involving behavioral momentum could be said to guess is debatable, and accounts of psychological momentum in human experimental participants do not appear to suggest explicit guessing.

Behavioral momentum and psychological momentum appear consistent with the remaining properties of dynamic representation proposed by Freyd (1987).

Table 2

Properties of Behavioral Momentum and Psychological Momentum Compared with Freyd's (1987) Suggested Properties of Dynamic Representation

Dynamic Representation	Behavioral Momentum	Psychological Momentum
Basic phenomenon (forward displacement or continuation)	Learned behaviors continue until acted upon by another force	Past success likely to lead to future success; past failure likely to lead to future failure
Depends upon coherent direction of motion	Disrupted if contingency between response and reinforcer is disrupted	Disrupted if the task is interrupted
Differs from guessing	?	?
Does not stem from sensory processes	Involves learned behavior	Involves learned behavior
Is impervious to practice or error feedback	?	Continued use of previously successful strategies even if no longer appropriate
A shift in memory for position (time)	Involves anticipated (future) behavior	Involves anticipated (future) behavior
Increases with increases in velocity	Increases with increases in reinforcement rate	Increases with increases in reinforcement rate
Occurs very rapidly	**Occurs hours, days, weeks or more after learning**	**Occurs hours, days, weeks or more after learning**
Increases over short retention intervals, then decreases	?	Stronger over (relatively) shorter temporal intervals
Attached to the represented object, not to an abstract frame of reference	?	?
Dimensions of change other than rigid transformations	Occurs for simple (key peck) and complex (reading) behaviors	Involves many different types of behavior

Note: Entries in **bold** indicate properties of behavioral momentum or psychological momentum that initially appear inconsistent with properties of dynamic representation (but see main text for discussion). A question mark indicates a lack of relevant data or other uncertainty.

One such property is that dynamic representation results in automatic extrapolation (displacement) of a target in the direction of motion. Behavioral momentum and psychological momentum each involve an increased likelihood of a continuation of the current behavior, and a continuation of behavior is analogous to an extrapolation of target motion. A related property is that the rate of change in dynamic representation increases with increases in the rate of change of the stimulus. Freyd phrased this in terms of target velocity; response rate is the behavioral equivalent of velocity, and behavioral momentum (Nevin, 1988; Nevin et al., 1983) and psychological momentum (Mace et al., 1992; Roane et al., 2004) each increase with increases in response rate. Another property proposed by Freyd is that changes in dynamic representation are not due to sensory processes. The time-scales of behavioral momentum and of psychological momentum are much longer than the duration of sensory processes. More critically, behavioral momentum (Podlesnik and Shahan, 2009; Podlesnik, Thrailkill, and Shahan, 2012) and psychological momentum (Kerick et al., 2000; Shaw et al., 1992) are influenced by manipulations that affect learning, and this suggests these two momentum-like effects result from learning (and other cognitive processes) and not from sensory processes.

Another property proposed by Freyd (1987) is that changes in dynamic representation depend upon a coherent direction of motion (e.g., representational momentum only occurs if the target maintains a consistent and predictable direction of motion). Behavioral momentum is disrupted if the contingency between response and reinforcer (analogous to a consistent direction) is disrupted (Nevin et al., 1983; Nevin and Shahan, 2011), and psychological momentum is disrupted if a task is interrupted (Briki, Doron, Markman, den Hartigh, and Gernigon, 2014; Eisler and Spink, 1998; Markman and Guenther, 2007). A related property is that changes in dynamic representation are not limited to rigid transformations, but this property might just reflect the types of stimuli (dots, geometric shapes) and changes (location, shape, size, etc.) typically used in experiments on representational momentum. It is not clear what would constitute a rigid or non-rigid behavior in the current context, but behavioral momentum and psychological momentum each involve complex behaviors that change along multiple dimensions, and considering all of these possibilities as "rigid transformation" does not seem plausible. A final property suggested by Freyd is that changes in dynamic representation are impervious to practice or error feedback. Given that behavioral momentum and psychological momentum are based upon learning, this might appear inconsistent, but the claim of imperviousness of representational momentum to feedback is overstated.[5] Even so, resistance to statistical interpretations of the hot-hand effect suggests psychological momentum might not be easily influenced by error feedback.

[5]Research subsequent to Freyd (1987) documented numerous ways that information provided to participants can influence representational momentum (for review, see Hubbard, 2005, 2014). Of relevance to the issue of error feedback are findings that participants who receive error feedback regarding their judgment of whether a subsequently presented probe is at the location at which a target vanished (Ruppel, Fleming, and Hubbard, 2009), or who believe a *same* response is less likely to be correct (Hubbard and Lange, 2010), are less likely to respond *same* to subsequent probes, although forward displacement per se is not influenced (i.e., height, but not skew, of the distribution of *same* responses as a function of probe location is influenced by error feedback). Also, participants who receive information regarding representational momentum (Courtney and Hubbard, 2008), or who receive advance cueing regarding final target location (Hubbard, Kumar, and Carp, 2009), exhibit smaller (but still statistically significant) forward displacement. These findings suggest representational momentum is not completely impervious to error feedback.

Advantages of Considering Behavioral Momentum and Psychological Momentum as Dynamic Representation

There are at least three potential advantages of considering behavioral momentum and psychological momentum as based on or involving dynamic representation. First, a more parsimonious understanding of momentum-like effects can be developed. Instead of positing multiple separate and unrelated momentum-like effects (and redundancies in mechanisms for their effects), a single more general mechanism that is able to anticipate future actions, behaviors, and outcomes at multiple time-scales is posited (for a similar argument involving other types of momentum-like effects, see Hubbard, 2014, in press; for an argument involving the importance of multiple time-scales of anticipation, see Jordan, 2013). Second, and relatedly, dynamic representation involves active processing and anticipation regarding likely actions, behaviors, and outcomes, and such an idea is in line with recent developments in forward modeling and in the study of links between perception and action. Third, and as discussed earlier, the idea of a more general dynamic representation that produces momentum-like effects leads to specific predictions that can be tested (e.g., processes suggested to rely on dynamic representation should exhibit properties consistent with dynamic representation, the effects of variables previously shown to influence one type of momentum-like effect provide hypotheses regarding the effects of those variables on other types of momentum-like effects, etc.), and regardless of the outcomes of such tests, the results of such experiments should shed considerable light on the understanding and application of momentum-like processes.

The Relationship of Behavioral Momentum and Psychological Momentum

Although the reviews of behavioral momentum and psychological momentum in Parts I and II, respectively, used broad categories involving characteristics of the target, context, and observer, the individual variables within each of those broad categories were different for behavioral momentum and for psychological momentum (e.g., characteristics of the target in behavioral momentum consisted of extinction, the partial reinforcement extinction effect, and resurgence; characteristics of the target in psychological momentum consisted of valence, direction, duration, mass, task, and prior probability). Similarly, variables within the broad categories for behavioral momentum and for psychological momentum differ from variables within the same broad categories for previously documented momentum-like spatial effects (see Hubbard, 2014). Differences regarding specific variables, and in determination of which variables might be analogous to other variables in other momentum-like effects, make it more challenging to consider the relationship between behavioral momentum and psychological momentum (and the relationships between these two temporal momentum-like effects to other types of [e.g., spatial] momentum-like effects). Even so, the possibility that behavioral momentum and psychological momentum each involve dynamic representation is consistent with the possibility that there is at least some overlap in the structures or processes involved in the different momentum-like effects.[6]

There are several possible relationships of behavioral momentum and psychological momentum. One possibility is that behavioral momentum and psychological momentum are separate and unrelated processes. However, this possibility seems inconsistent with the many similarities of behavioral momentum and psychological momentum noted earlier, as well as inconsistent with the similarities of momentum-like effects more generally (see Hubbard, in press). A second possibility is that psychological momentum is a subset or special case of behavioral momentum or that behavioral momentum is a subset or special case of psychological momentum. The data do not yet suggest whether behavioral momentum or psychological momentum is the more inclusive (although it might be easier to reduce psychological momentum to behavioral momentum than to reduce behavioral momentum to psychological momentum). A third possibility, and as suggested earlier, is that behavioral momentum and psychological momentum reflect the same general phenomenon, with the modifier "behavioral" applied when describing an observed behavior and the modifier "psychological" applied when describing a reported subjective experience. Indeed, the historically separate notions of "behavioral momentum" and "psychological momentum" might be examples of construct proliferation, in which the same general phenomenon is given different names by different groups of researchers working within different paradigms.

Part IV: Conclusions

Behavioral momentum and psychological momentum each involve a continuation (extrapolation) of current behavior. Despite this, there has been relatively little comparison of these two momentum-like effects. Although behavioral momentum has usually been studied within the framework of learning theory and with nonhuman animals or with humans diagnosed with developmental or learning disorders, and psychological momentum has usually been studied within social psychology and sport psychology with normative human participants, there are significant

[6]Similarly, studies on behavioral momentum tend to focus on the connection between environmental contingencies and exhibited behaviors, whereas studies on psychological momentum tend to focus on the connection between reported states and a mental construct. This difference maps onto the distinction between functional approaches and cognitive approaches discussed by De Houwer (2011; De Houwer, Barnes–Holmes, and Moors, 2013), with research on behavioral momentum focusing more on function and research on psychological momentum focusing more on cognition. An attempt to find commonalties between behavioral momentum and psychological momentum such as those in Table 1 and in comparison of dynamic properties in Table 2 can be viewed as an attempt to bridge functional and cognitive approaches to momentum-like effects.

similarities of these two types of momentum-like effects (e.g., increases in reinforcer rate or quality increase momentum-like effects, subsequent low probability behaviors are considered more likely if success or compliance was previously established, etc.). The similarity of ideas from such different paradigms points to deeper principles regarding adaptiveness of behavior and cognition to environmental contingencies and regularities. Despite differences in methodology and nomenclature, behavioral momentum and psychological momentum appear to be closely related, and might even reflect the same general processes, albeit in different forms. This is consistent with Newton's theory (on which the momentum metaphor is based), which clearly demonstrates that phenomena that might initially appear very different (e.g., motions of Earth-bound objects and motions of celestial objects) can nonetheless be governed by the same laws and principles.

Behavioral momentum and psychological momentum exhibit many of the properties previously attributed to dynamic representation. However, consideration of other momentum-like effects involving dynamic representation has previously been limited to processes that occur at much shorter time-scales. The existence of behavioral momentum and of psychological momentum suggests that dynamic representation can occur at different time-scales and is not necessarily limited to very short time-scales. Indeed, the possibility of different time-scales underscores the importance of temporal information (regarding change or transformation associated with a given duration or range of time) in dynamic representation. This suggests not only a connection between behavioral momentum and psychological momentum, but also the possibility of deeper principles connecting behavioral momentum and psychological momentum with other types of momentum-like effects (e.g., see Hubbard, in press). Even if momentum-like effects do not influence future behavior directly, behavioral momentum and psychological momentum are useful as heuristics in predicting behavior. Furthermore, behavioral momentum and psychological momentum demonstrate important ways in which organisms are actively engaged with stimuli and not just passive recipients or observers; in behavioral momentum and in psychological momentum, this active engagement takes the form of anticipating actions and behaviors and is based on dynamic representation.

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