Unpacking Conflict and Uncertainty in Decision Difficulty: Testing Action Dynamics in Intertemporal Choice, Gamble Choice, and Consumer Choice

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Abstract

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Previous studies measured decision difficulty with self-report or decision deferral without clarifying the specific psychological states underlying difficulty. The present study aims to unpack decision difficulty by testing action dynamics based on mouse (cursor) tracking across intertemporal, gamble and consumer choices. Across different decision domains, multiple action dynamic measures could be grouped into three orthogonal components: Conflict, Wavering and Locomotion. Moreover, the Conflict component was most sensitive to the sign of the context, with more conflict being experienced in the loss than in the gain context. By contrast, the Wavering component was most sensitive to the similarity between the options, with more wavering flips being exhibited when the options were more similar. The study also found that choosing the long-term advantageous options in the intertemporal choice task, choosing the riskier gain and safer loss in the gamble choice task, and choosing the more expensive/better-quality hotel in the consumer choice task was associated with greater conflict and/or wavering. The study further found that numeracy was negatively related to idle time and the Conflict component. Taken together, the study demonstrated that decision difficulty was contextual- and individual-dependent, and could be described and unpacked by dynamic behavioral measures.

Dedication

To my wife and parents.

Acknowledgments

I would like to thank you my advisor, Dr. Claudia González-Vallejo for her support to my academic adventure at Ohio University.

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Introduction

Experiencing difficulty when making decisions is common in many domains. For example, when planning a trip, a hotel that provides excellent customer services (e.g., cleanness, transportation, safety, entertainment, etc.) is desirable. However, superior services are usually offered at a higher price. Therefore, consumers have to make trade-offs between the quality of services and the cost and hence experience difficulty in the process[1] (Chatterjee & Heath, 1996; Luce, Payne, & Bettman, 1999). In addition to the inherent dilemma of making trade-offs, the characteristics of the decision context also impact decision difficulty. For example, it is much easier to make trade-offs when buying breakfast beverages than having to decide when and how to pay off student loans (Kristof, 2009). Research on the topic of decision difficulty has found that people experience more difficulty when making choices dealing with losses than with gains, possibly due to the negative emotion elicited by the losses (Luce et al, 1999).

Over the past decades, a number of studies have identified some of the sources that lead to decision difficulty, and how those sources impact final decisions. Indeed, maximum difficulty may lead to no decision at all and hence decision deferral (Anderson, 2003). It is commonly assumed that difficult decisions demand more time to think; however prior studies have not advanced a systematic study of this question. It is also unclear whether different sources of difficulty are experienced in the same manner and affect final decisions in the same ways. For example, one may experience difficulty in a

[1] In the current work, I refer decision difficulty to the *subjective experience* of difficulty when making decisions, which is consistent with the definition of "the level of perceived difficulty or ease of selecting among choice options" in Hanselmann & Tanner (2008).

fast food restaurant when ordering food because the food on the menu has similar subjective utilities. On the other hand, a high school graduate may feel it is difficult to choose which college to study: one has a higher rank but is more expensive, whereas the other is cheaper but with a lower rank. The decision is difficult to make in this case because both advantages and disadvantages are important and trade-offs are in demand.

The measures of experienced difficulty based on holistic self-reports (Chatterjee & Heath, 1996) or response time (Luce, 1998; Anderson, 2003) are not able to elucidate the sources of decision difficulty in various domains. Furthermore, few studies have examined the psychological states prior to making final decisions and their relationship to task characteristics that may elicit varying levels of difficulty.

The study of decision processes via action dynamics of cursor movements is fairly new and may be used to advance knowledge on the topic of decision difficulty. The measures of action dynamics are able to provide continuous and dynamic trajectory information that depicts *how* a choice is made in a particular circumstance (e.g., Koop & Johnson, 2011, 2013; Taylor & Ivry, 2013; Gallivan & Chapman, 2014). To facilitate the understanding of trajectory tracking, Figure 1 illustrates a sample trajectory of a participant making a choice; this screen shot was taken from Cheng & González-Vallejo (2015). In the program, to start a trial, participants move the cursor to the center-bottom of the frame (the frame was smaller than the screen, and participants cannot move the cursor outside this frame) to click the start button. After clicking, the start button disappears, and two options appear on the left and right sides of the screen, respectively. Under each option, there is a "Select" button. Participants move the cursor from the start point to a "Select" button to complete the choice. Once selected, the two options disappear and the start button appears again for the next trial.

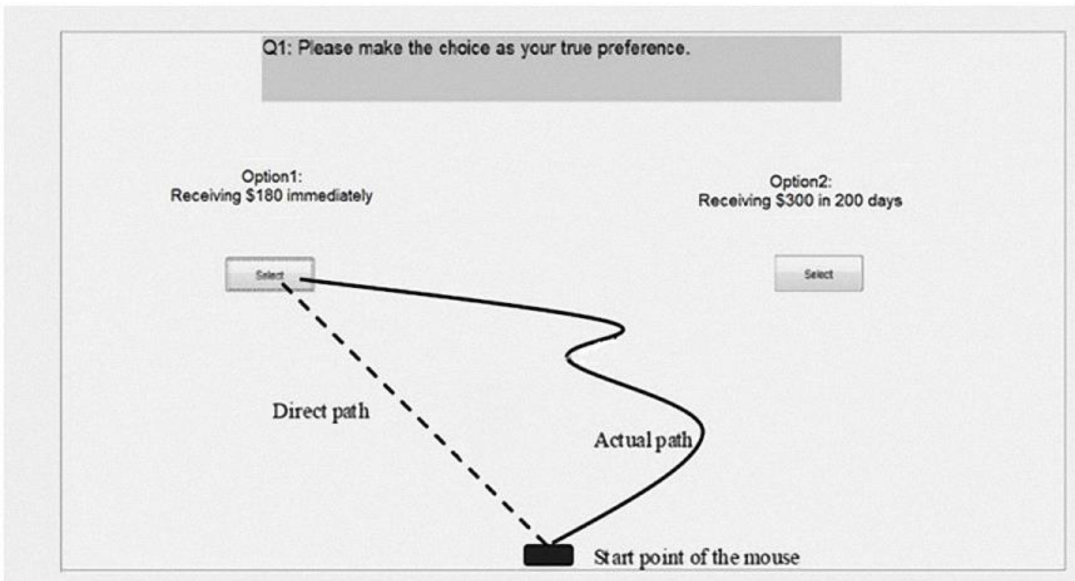

Figure 1. Choice task screenshot with hypothetical paths: direct (dotted line) and indirect (solid curved path).

The information acquired from the trajectory contributes to the understanding of decision-making. Take gamble choice as an example. In Koop & Johnson (2013), participants were asked to choose between options such as "You have 80% chance of winning $60" and "You have 90% chance of winning $50". Results showed that participants had more deviant trajectories when choosing a risky gain over a safe one, but the pattern was reversed (and less pronounced) in the loss domain, indicating that choosing the risky gain and the safe loss over their respective counterparts led to more reluctance, possibly due to the fact that making such choices went against a basic tendency towards selecting the safe option with gains, and the risky option with losses (Kahneman & Tversky, 1979). Figure 2 (acquired from Koop, 2013) depicts such a pattern with trajectories aggregated across participants, with square box as the chosen option, the vertical line indicates the middle between the two options, and 0 in the x-axis as the starting point.

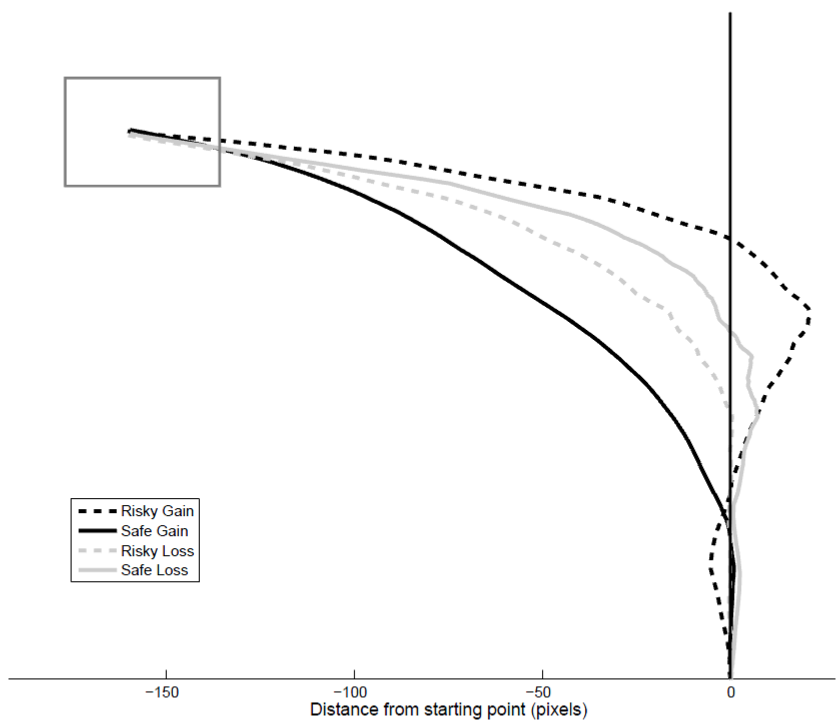

Figure 2. Mouse trajectories in the gain and loss conditions in gamble choice (Koop & Johnson, 2013).

Therefore, the methodology of action dynamics has the potential to address the aspects of decision process that relate to decision difficulty. For example, based on self-report and decision deferral, decision difficulty has been linked to the similarity of options' attractiveness (Dhar, 1997). Accordingly, in a study of inter-temporal choices (where participants must make trade-offs between money and delay) it was found that when the subjective value of the options were similar, the curvature of the trajectory (the area between the trajectory and the hypothetical straight line between the start point and the chosen option) was larger, indicating that people were less decisive when making a choice in such a situation (Dshemuchadse, Scherbaum & Goschke, 2013). Hence, with an action dynamic measure, the study illustrated how decision process was affected by decision difficulty stemming from the similarity (or discriminability) between the options.

The methodology of action dynamics has great potential to advance the knowledge of decision-making but is not free of limitations. A series of measures (for more details please refer to Table 1) based on temporal response and trajectory have been tested in gamble choices (Koop & Johnson, 2013), intertemporal choices (Dshemuchadse et al, 2013; Cheng & González-Vallejo, 2015) and moral dilemmas (Koop, 2013). However, the construct validity of these measures has yet to be fully understood. For example, it is not known whether more directional flips between the options represent more conflict or more ambivalence. In the standard intertemporal choice paradigm, as well as in other matching paradigms, decision makers make choices in order to equate value or reach an indifference point (see Cheng & González-Vallejo, 2015, for an example). In theory, when participants are indifferent between the options, decisions are more difficult to make.[2] Nevertheless, decisions are also difficult when options are dissimilar but have both salient advantages and disadvantages (hence decision-makers have to put effort into making trade-offs). Up to now, it is not clearly known if different action dynamic measures can differentiate the different sources of decision difficulty (but see González-Vallejo, 2015). Therefore, the psychological states experienced by individuals in varying conditions and the corresponding measures obtained from action dynamic techniques demand further exploration.

Psychological States and Decision Process Measures

The present study hypothesizes that individuals experience varying psychological states when making decisions and these are reflected in temporal and spatial action dynamics measures. In particular, the current thesis assumes that psychological conflict is distinct from psychological uncertainty. Furthermore, these states are reflected by different action dynamics measures. The study will focus on manipulating conditions that are expected to affect these psychological states, and corresponding measures, in varying and predictable ways. The hypothesis has received some support in the domain of intertemporal choice (Cheng & González-Vallejo, 2015), and the current work aims to test the hypothesis in more decision tasks. The following sections first review the concept and measurement of decision difficulty, and then they detail the experimental

[2] Decisions are not necessarily difficult when people are indifferent between the options if the decision is not important. For example, students may not really feel difficulty when choosing between two similar pens before doing the homework. However, in the present study all decision tasks involve trade-offs between money and other attributes, and are adopted to reflect decisions in real life (e.g., choosing a hotel when planning the trip), it is assumed that decisions are more difficult when options are similar or subjectively identical.

manipulations that are expected to affect general decision difficulty that can be further differentiated into the constructs of conflict and uncertainty states with specific dynamic measures.

Sources that Lead to Decision Difficulty

Decision difficulty has been frequently addressed in decision-making research, yet it has been rarely clearly defined. Decision difficulty was been defined as "the level of perceived difficulty or ease of selecting among choice options" in Hanselmann & Tanner (2008). As argued in Anderson (2003) and Broniarczyk & Griffin (2014), decision difficulty is hard to define without describing how it is measured. In line with the definition given by Hanselmann & Tanner (2008), a number of studies employ self-reports to measure it (e.g., Chatterjee & Heath, 1996; Zhang & Mittal, 2005; Hanselmann & Tanner, 2008; Thompson, Hamilton & Petrova, 2009). For example, in Thompson et al, (2009), the authors adopted a seven-point scale to ask participants to rate how difficult the decision was. In addition, decision deferral (or decision avoidance) has been used to measure decision difficulty (Dhar & Sherman, 1996; Dhar, 1997; Dhar & Nowlis, 1999). Decision deferral may be caused by demanding more time to search for better options, to solve the conflict, or to avoid taking the responsibility, all of which deal with a difficult decision situation (Anderson, 2003). Similar to decision deferral, response time has also been used, assuming more difficult decisions require more time to process (McClure, Laibson, Loewenstein, & Cohen, 2004; Chabris, Laibson, Morris, Schuldt, & Taubinsky, 2008).

Specific aspects that appear to relate to the decision difficulty across various studies are:

Making trade-offs. In most decision domains, dominant options (e.g., hotels that have high quality rankings and cost less) are hard to come by. For decisions under uncertainty, Pleskac & Hertwig (2014) performed an ecological analysis and found that risks and rewards were inversely related in many real world domains. Hence, people have to make trade-offs between different attributes, such as deciding to invest in a low probability high payoff venture versus a high probability low payoff one. Making trade-offs leads to conflict because the options under consideration have both advantages and disadvantages (Dhar, 1997; Luce, 1998; Luce, Payne & Bettman, 1999; González-Vallejo, 2002). In a consumer choice study, participants (college students) were asked to make a choice between two equally priced apartments. The difference was that one apartment was larger but distant, whereas the other apartment was smaller but closer to campus. One group of participants were required to consider how the apartments would affect their daily routine in terms of size and distance (process-oriented condition), whereas the other group of participants were asked to only consider the benefits brought by the apartments (outcome-oriented condition). As one could imagine, in the process-oriented condition, participants were guided to make trade-offs between distance and size because they were asked to take both attributes into account. In contrast, in the outcome-oriented condition, participants simply considered the advantage of each apartment. As a result, participants in the process-oriented condition rated the decision as more difficult to make. Meanwhile, they also reported a higher level of negative emotion when compared to the participants in the outcome-oriented condition (Thompson et al, 2009).

Furthermore, as people have to make trade-offs, selecting different options may be accompanied with different levels of trade-offs and hence different levels of experienced difficulty. For example, participants were asked to make trade-offs between safety and price when considering which car to purchase, and it was found that trade-off difficulty (measured by self-report) was positively related to the preference toward the car with better safety features but also with a higher price tag (Luce et al, 1999). In intertemporal choice, choosing the later larger gain appeared more difficult than choosing the sooner smaller gain because people had to overcome the temptation of receiving the money earlier and thus make trade-offs (Dshemuchadse et al, 2013).

Decisions about moral dilemmas also exhibit similar patterns. A moral dilemma refers to a conflicted situation in which people need to choose one option among the alternatives, and there is no optimal solution as each option brings positive and negative outcomes. In Koop (2013), participants were asked to imagine that they were in a diving team to deactivate old World War II underwater anti-ship mines. One member scraped himself and the blood attracted several sharks. This diver was swimming towards the last protective shark cage and would reach it before any others. Thus, participants were given two options: suppose that they had a gun, (a) shoot the diver, let sharks eat him so that participants and other members were saved, or (b) let the diver reach the cage. In this case, both participants and the other members would be eaten by sharks. Option (a) represents a utilitarian response and requires more benefit calculation (saving more people is better than saving one person). Nevertheless, this option requires the participants to actively kill the diver, which is morally aversive. Whereas option (b) is a deontological response because it follows the moral criterion. However, option (b) leads to more deaths. Participants were asked to rate the difficulty that they experienced when making such choices. It was found that participants felt greater difficulty when choosing the deontological option, indicating that it might be harder to follow the moral criterion which leads to a more negative objective outcomes (e.g., more deaths). In terms of action dynamic measures, the higher the rated difficulty, the more deviant the trajectory was. Hence, the study demonstrated that the type of trade-off being made affected the difficulty experienced and these were shown in the characteristics of the paths towards the final decision. Furthermore these paths varied depending on whether the final choice was the utilitarian or the deontological response.

Decisions with similar options. It is believed that when the attractiveness of the options is similar, the situation contains more uncertainty and hence increases decision deferral in consumer choices (Payne, Bettman, &Johnson 1992; Dhar, 1997; Dhar & Nowlis, 1999; Anderson, 2003). Similarly in intertemporal choice, when the alternatives presented to a participant were approaching the person's indifference point (i.e., the options are subjectively closer), the situation was viewed as more uncertain (Chabris et al, 2008; Dshemuchadse et al, 2013). As a result, participants took more time to make a choice (Chabris et al, 2008) revealing greater decision difficulty. In another intertemporal choice task (McClure et al., 2004), there were two conditions where the delays were exactly the same. The difference was that the money difference was smaller in one condition than the other. The condition with the smaller money difference was defined as more difficult by the authors, and consistently, participants exhibited longer response times in this situation.

Decision with losses. Prospect theory contends that a loss looms larger than a gain keeping the objective magnitudes the same (Tversky & Kahnemann, 1991). This assumption is used to explain loss aversion (i.e., individuals prefer to take a gamble involving a loss than a sure loss of equal expected value). Accordingly, researchers further assume that people experience stronger negative feelings when making choices among losses than when making choices with gains, even if the magnitudes are the same between the contexts (Luce et al, 1999; Anderson, 2003). It is believed that the negative emotion elicited by loss increases decision difficulty (Chatterjee & Heath, 1996). Furthermore, making choices in the loss context deals with the avoidance-avoidance conflict, which is more difficult than dealing with the approach-approach conflict (Dhar & Nowlis, 1999; Anderson, 2003). For example, in Dhar & Nowlis (1999), in the approach-approach conflict condition, two apartments had unique advantages (e.g., new furniture vs. color TV) but common disadvantages (e.g., no parking space). Hence, participants only needed to compare the advantages between the apartments. Similarly, in the avoidance-avoidance conflict condition, two apartments had unique disadvantages but common advantages. Thus, participants needed to focus on the negative attributes. It was found that decision deferral was less frequent in the approach-approach conflict condition than in the avoidance-avoidance conflict condition.

Thus, compared to the gain context, the loss context appears more difficult in terms of reaching a decision. In another consumer product study, participants were asked to choose a camera between two options framed differently. In the loss-framed condition, participants were informed that there was a superior camera (better quality and cheaper price) but it was no longer available. Hence, participants were guided to believe that they missed a better deal and suffered a loss. In contrast, in the gain-framed condition, an inferior camera was added (with poorer quality but higher price) to serve as the reference point so that the two target cameras appeared even better. Thus, participants were led to believe that they made some gains from the improvement of the target cameras by adding an inferior one. As a result, participants reported that it was more difficult to make a choice in the loss-framed condition than in the gain-framed condition, despite that the two target cameras remained the same between the two conditions (Chatterjee & Heath, 1996).

Cognitive sources of difficulty. Decisions often involve numerical information. In gamble choices, options are expressed with money and probability. In intertemporal choices, people make trade-offs between money and delay. Consumer products are also presented with numerical information such as price and quality rating (e.g., in Amazon, Booking.com). Therefore, it is critical for decision-makers to understand and process numerical information when they are making choices. Depending on the amount of information that is considered, decisions can be particularly challenging.

Numeracy refers to the cognitive ability to process basic probability and numerical concepts (Peters, Vastfjall, Slovic, Mertz, Mazzocco, & Dickert, 2006). It has been found that individual differences in numeracy affect judgment and decision-making. For example, for high numerate people, their perception of likelihood was less likely to be affected by how the likelihood was expressed: in percentage or in frequency (e.g., .1 was presented as 10% or 10 out of 100). In contrast, low numerate people tended to largely underestimate the likelihood when it was presented in the percentage format (Peters et al, 2006).

Numeracy pertains to an internal cognitive ability. However, it also relates to problem structure. When problems involve lots of numerical information, the ability to process such information is particularly important. For example, making investment decisions requires the processing of companies' portfolios, which are represented by a series of numbers. Further, the investor needs to take probability, timing, and other constraints into account. Thus, numeracy is likely to play a significant role when people are engaging in a series of choices that contain different numerical information.

So far there has been little empirical research directly addressing decision difficulty and numeracy. Conceptually, if low numerate people have difficulty in processing numerical information (Reyna, Nelson, Han & Dieckmann, 2009), it is likely that they may experience greater decision difficulty when making decisions that demand numerical comparisons.

Action Dynamics to Understand Decision Difficulty

This section reviews a series of action dynamic measures that have been used by researchers as presented by Cheng & González-Vallejo (2015).[3] The Cheng & González-Vallejo study also serves as the basis for motivating the goals of the current proposal.

Trajectory recording program. The study of psychological processes with computer-based methodology is rather new. The methodology involves processing tracing methods, which track individuals' search for information in grids describing options and their corresponding attributes (Johnson, Payne, Bettman & Schkade, 1989). More recently, action dynamic measures generated from cursor or hand movements[4] (see Figure 1) have been employed in judgment and decision-making research to analyze cognitive operations (Spivey, Grosjean, & Knoblich, 2005; McKinstry, Dale & Spivey, 2008; Freeman & Ambaby, 2010). For example, Spivey et al. (2005) examined the trajectory of mouse movements when participants made selections between two similar (dissimilar) words they heard. It was found that the trajectory appeared less straightforward when the two words sounded similar (candle vs. candy), suggesting that the spatial pattern followed with the mouse indexed judgment difficulty due to the overlapping phonetics. In the visual domain, the trajectories were more deviant when choosing between two similar than dissimilar pictures (Koop & Johnson, 2013). Hence,

[3] Large portions of the text in this section is taken from the Cheng & González-Vallejo (2015) manuscript.
[4] Action dynamic measures generated based on hand movements (i.e., reach trajectory, see Taylor & Ivry, 2013; Gallivan & Chapman, 2014) can index similar effects compared to cursor trajectory. The current work employs cursor trajectory, hence, we discuss research that adopts cursor movements as data source.

action dynamic measures have the capacity to depict the process underlying decisions and inform about the basis of decision difficulty.

To better explain the methodology of measuring the trajectory, Table 1 presents the measures that were used in previous studies with their definition/description (Spivey et al, 2005; Dale, Roche, Snyder, & McCall, 2008; Duran, Dale &McNamara, 2010; Freeman & Ambady, 2010; Koop & Johnson, 2011, 2013; Koop, 2013; Dshemuchadse et al, 2013; Cheng & Gonález-Vallejo, 2015). Among these studies, some employed action dynamic measures to examine choice behavior (Koop & Johnson, 2011, 2013; Koop, 2013; Dshemuchadse et al, 2013; Cheng & González-Vallejo, 2015), whereas others focused on learning behavior (Spivey et al, 2005; Dale et al, 2008), and deception behavior (Duran et al, 2010). Freeman & Ambady (2010) provides a review of action dynamics software and relevant measures.

Table 1

Descriptions of action dynamic measures

Measure	Description	Possible Psychological State	Reference
X-flip	Number of directional changes along with the x-axis during a trial	Preference reversal; uncertainty	Duran, Dale & McNamara, (2010); Koop & Johnson, (2013); Koop, (2013)
AAD (Average Absolute Deviation)[b]	Mean absolute deviation from the direct path during a trial. The direct path refers to the most straightforward path between the start point and the chosen option	Competition/conflict	Freeman & Ambady, (2010); Koop & Johnson, (2013); Koop, (2013);
MAD (Maximum Absolute Deviation)[b]	The maximum deviation between real path had hypothetical direct path	Peak competition/conflict	Koop & Johnson, (2011, 2013); Koop, (2013)
Curvature	Area between the real path and direct path	Competition/conflict	Dshemuchadse et al, (2013)
Distance[b]	The cursor movement distance during a trial	Overall decision difficulty	Dale et al, (2007); Duran et al, (2010); Koop & Johnson, (2011, 2013); Koop, (2013)
Idle time[a]	Amount of time when the cursor is paused during a trial	Thinking; distraction	Cheng & González-Vallejo (2015)
Motion time[a]	Amount of time when the cursor is in motion during a trial	May contain periods of thinking or distraction	Cheng & Gonález-Vallejo (2015)
$RT_{latency}$[a]	Amount of time when the cursor stays in the latency region (i.e., 100- or 200-pixel radius around the start point)	Thinking/ embryoperiod	Dale et al, (2008); Duran et al, (2010)
RT_{motion}[a]	Amount of time when the cursor leaves the latency region during a trial	Implementing preference	Dale et al, (2008); Duran et al, (2010)

[a] Measured in seconds; [b] measured in centimeters or pixels.

As illustrated in Table 1, a series of measures have been used to depict a trajectory. Distance indexes the global distance that the cursor travels during a trial, and when the trajectory is less straightforward, distance is longer, but the reverse is not necessarily the case (e.g., moving the cursor along the direct choice path repeatedly).

More subtle patterns underlying cursor movements are captured by X-flip, AAD, and MAD. X-flip may index an explicit preference reversal if the decision-maker clearly reverses the direction of the cursor at some point during a trial (i.e., clear sway). In such instances, X-flip would be positively related to the overall traveled distance (Distance). Nevertheless, X-flip may represent subtle wavering, or small fluctuations between the alternatives, indicating a pattern of uncertainty. If so, X-flip may not be related to Distance because subtler wavering does not significantly increase the overall distance that the cursor travels. Hence, analyzing the relationship between X-flip and other measures helps to illustrate whether X-flip indexes preference reversal or uncertainty.

In terms of AAD, researchers have viewed this measure as a reflection of the competition (pull and push) or conflict between the two alternatives (Koop & Johnson, 2013). AAD is expected to logically relate to overall Distance as larger deviations should result in greater traveled distance. However, its relationship with X-flip is less clear because a deviant path does not necessarily imply more directional flips.

MAD also indexes competition and conflict. However, it depicts the peak conflict experience during a trial. MAD is believed to be "*better at highlighting differences occurring in the "heart" of each trial*" (Koop, 2013, p12). MAD is not necessarily correlated with X-flip. However, a larger MAD adds to AAD and Distance.

In terms of the temporal measures, Koop & Johnson (2011) found that response time, a traditional process measure, was not related to trajectory measures when studying gamble choices, and perhaps this was because response time is too gross. Hence, Cheng & González-Vallejo (2015) further divided response time into idle and motion time. For idle time, it is possible that it indexes thinking time, or alternatively, it indexes distraction. Further, thinking time may be related to solving a decision conflict. If thinking facilitates solving the conflict, then idle time would be expected to be negatively related with other trajectory measures such as AAD. In contrast, if thinking is induced by difficulty or conflict and does not facilitate decision-making, the measures are expected to correlate positively. That is, longer time idling is associated with more deviant paths. Finally, if the idle time represents distraction, no relationships with path measures would be expected. These possibilities were tested in Cheng & González-Vallejo and are reassessed in the current investigation.

Unpacking decision difficulty in intertemporal choice and testing construct validity of action dynamic measures. Most studies reviewed thus far either used a single dynamic measure to index a psychological process (e.g., Dshemuchadse et al, 2013), or multiple measures but testing them separately (e.g., Koop & Johnson, 2013). The single measure approach is problematic because it misses the possible relationships among the measures. For example, without specifying the relationship between Idle time and other measures, it is unclear if Idle time indexes conflict (i.e., positively related with AAD), or distraction (not related with other measures). In addition, a single measure approach fails to show measures' varying sensitivities in different situations. For example, as described above, although multiple measures can capture the behavioral patterns near the indifference point in intertemporal choice, the degree of their variation may be different. As a result, it is unclear which psychological state (e.g., uncertainty, conflict or something else) is most evident when choices are closer to the indifference point.

To address this issue, Cheng & González-Vallejo (2015) took a correlational approach and examined the degree of overlap of the temporal and spatial measures. As shown in Table 2, Idle time is positively associated AAD, Motion time is positively related to Distance, and X-flip is not significantly related to any other measure. These findings implied that the measures captured different aspects of decision process. More specifically, Idle time and AAD were interpreted as measures of the competition between the options, and hence they were likely to represent conflict when people are making trade-offs. Whereas X-flip appeared to index uncertainty because more X-flips did not increase the total distance travelled. Distance and Motion time appeared to depict an overall locomotion function without further psychological meaning per se, as it takes time to make cursor movements when making the choices.

Table 2

Correlations among decision process measures In Cheng & González-Vallejo (2015, Experiment 2)

	AAD	X-flip	Distance	Idle Time	Motion Time
AAD	----	.19	.26	.45	.01
X-flip		----	.13	.19	.04
Distance			----	.21	.42
Idle Time				----	.09

To further unpack decision difficulty in varying situations, principal component analysis (PCA) was applied to the five measures (AAD, X-flips, Distance, Idle time and Motion time) and the overall decision difficulty was described by two components: Conflict, depicted by Idle time and AAD, and decision uncertainty or Wavering, described by X-flip (Table 3). The Conflict PC was best at capturing the gain/loss and magnitude context effects. That is, greater Conflict was observed in the loss context and the small magnitude condition, indicating competition between the options was most salient in such situations. When choices were closer to the indifference point, the PC of Wavering was most salient. This finding was consistent with the conclusions about uncertainty reached by Chabris et al, (2008) and Dshemuchadse et al, (2013). In terms of what was selected and the components, Conflict, Wavering and locomotion all showed a larger value when selecting later larger gains than when selecting the sooner smaller ones, suggesting that selecting the later larger gains entailed more significant cognitive effort and uncertainty. Moreover, there was no difference in the ability to capture the Process measures conditional on final choice between the Conflict and Wavering components.

Table 3

Principal component analysis for action dynamic measures In Cheng & González-Vallejo (2015, Experiment 2)

	Rotated Components			Communalities
	1	2	3	
AAD	**.86**	.05	.09	.74
X-flip	.12	.05	**.99**	.99
Distance	.27	**.79**	.07	.70
Idle time	**.82**	.10	.08	.69
Motion time	-.08	**.88**	-.004	.78
Eigenvalues	1.83	1.21	.88	
Variances accounted (%)	36.67	24.10	17.51	

Note: A loading that is greater than .6 is used as a threshold for component assignment (Comrey & Lee, 1992).

Therefore, with action dynamics, the study replicated the finding that intertemporal choices were more difficult in the loss context than in the gain context, in the small magnitude condition than in the large magnitude condition (Paglieri et al, 2013), when options were more subjectively similar, and when selecting the later larger gains over the sooner smaller ones. More importantly, the study demonstrated that decision difficulty varied with decision situations, and the different aspects of decision difficulty were differentially measured by principal components of action dynamic measures. The study showed that difficult decisions may entail conflict due to the inherent tension of making trade-offs and this was measured with the PC Conflict; difficulty may also result from the inability to make comparisons as when options are close in value (or perceptually similar), and this was depicted by the PC Wavering. This is a novel theoretical advancement as it begins to shed light on the behavioral pattern and its underlying psychological state of decision difficulty.

Goals of the Present Study

The primary purpose of the current work is to better understand the psychological states of decision difficulty in different decision domains. In particular, this work aims to focus on the states of *conflict* and *uncertainty* as differentiated by Cheng & González-Vallejo (2015), and to further advance the validity of the dynamic measures assumed to represent such states. Two general hypotheses will be tested to examine the construct validity of action dynamic measures. It is first hypothesized that different action dynamic measures can be grouped into different components to represent different aspects of decision difficulty. Furthermore, it is also hypothesized that the variation of the derived components depends on the decision context. By testing these two hypotheses, the study aims to unpack decision difficulty, and clarify the validity of action dynamic measures.

Several domains were used to systematically examine the variability of conflict and uncertainty and test the generalizability of the earlier findings. The domains examined are intertemporal, risky (gamble) and consumer choices. These three tasks represent different decision realms widely studied by judgment and decision making researchers (Weber & Johnson, 2009). Risky choice represents decisions under risk, with options containing explicit probabilities. Consumer choice concentrates on decisions under certainty, assuming quality and price are fixed at the moment of making decisions. Intertemporal choice stands on its own because although the attributes of money and time are clearly stated and fixed, people might take uncertainty into account due to the relationship between time and risk (Bixter & Luhmann, 2015).

The analytical approach used in the current work is similar to the one used in Cheng & González-Vallejo, (2015). That is, the variation of action dynamics is examined with the aid of PCA. The component level analysis further advances construct validity of action dynamic measures and the degree to which the variation in components corresponds with predicted effects in decision processes (e.g., the Conflict component should be more sensitive than the Wavering component to the gain-loss contextual variation).

Three experiments were conducted. Experiment 1 focused on whether action dynamics vary between the gain and loss conditions in both intertemporal and gamble choice tasks. In particular, this experiment tested whether the component that represents Conflict (possibly including AAD and Idle time as shown in Cheng & González-Vallejo, 2015) was most sensitive to the change of gain-loss frame. Experiment 2 focused on the role of similarity in intertemporal and gamble choices. It was expected that the Wavering component (i.e., directional flip measure) would show the most variation when the similarity between the options was manipulated. Experiment 3 adopted a consumer choice task and aimed to test the impacts of similarity and task importance on the experience of conflict and uncertainty when participants make trade-offs between quality and price. More details about the hypotheses are found in the experimental design section.

Furthermore, in all experiments the processes associated with the final choices (i.e. selecting different options) was examined with regards to conflict and uncertainty.

That is, the study examined the variation in conflict and uncertainty conditional on final choices.

In addition to options requiring trade-offs, dominant options were included in order to depict the baseline level of conflict and uncertainty. Dominance refers to having advantages in all dimensions. For example, in the choice pair of receiving $100 now vs. receiving $50 in 1 month, the former option is the dominant one because it offers more money in less time. The dominant option is thus easy to select and the situation serves as a manipulation check for the measures. At the preference level, it is hypothesized that participants will always choose the dominant option if it is available in accordance with rational choice principles (Savage, 1954). At the process level, all measures are expected to show the smallest values as these situations should result in little conflict or uncertainty. Moreover, when choosing the dominant option, the process is not expected to be affected by situational factors (e.g., sign, similarity).

In terms of individual differences, this work measured numeracy in order to clarify its role in the decision process. In particular, low numerate people were assumed to experience more conflict, and/or uncertainty. Taken together, the present study addressed both psychological states in varying decision situations, as well as the role of a person level trait in decision difficulty.

Experiment 1

Experiment 1 aimed to compare decision process between the gain and loss contexts in intertemporal and gamble choices. Based on the research reviewed, the hypotheses are:

Hypotheses in Experiment 1

Structure of action dynamic measures (H1). It is hypothesized that in both intertemporal and gamble choice tasks, the psychological states of conflict and uncertainty can be differentiated by different action dynamic measures. Using results from Cheng & González-Vallejo (2015), Table 3 illustrates that based on Principal Component analysis, the five action dynamic measures can be divided into three orthogonal components. The combination of Idle time and AAD is likely to index the conflicted experience because AAD taps into the competition between the options. The positive relationship between Idle time and AAD also indicates that Idle time deals with thinking instead of distraction. This component is labeled Conflict. X-flip itself constitutes a component, implying that it captures a unique aspect of decision process. The component behind X-flip is likely to depict uncertainty because the measure depicts wavering movement between the options. Hence, this component is labeled Wavering. Additionally, the component with Distance and Motion presents the information of general movement function, and hence, it is named Locomotion. The current work expects to replicate such a three-component structure in both decision tasks.

The effect of gain vs. loss (H2). In both tasks and for experimental choice pairs (thus participants have to make trade-offs between attributes), it is expected to find more conflict and uncertainty (defined by the components generated in H1) in the loss context than in the gain context. This is because avoidance-avoidance conflict (loss context) is more difficult than the approach-approach conflict (gain context), and making choices in the loss domain is accompanied by the negative emotion which leads the choice to be more difficult. Furthermore, H2 hypothesizes that the Conflict component will show a larger variation than the Wavering component between gain and loss contexts. In other words, the main source for the decision difficulty when dealing with gain-loss frame is conflict instead of uncertainty. As displayed in Figure 3, the Conflict component (based on Idle time and AAD) was more sensitive than the Wavering component (based on X-flip) in intertemporal choice (Cheng & González-Vallejo, 2015). The study expects to replicate this effect in both intertemporal and gamble choices. In terms of when facing choice pairs with a dominant option, as discussed earlier, the process is not expected to be affected by the sign of the context.

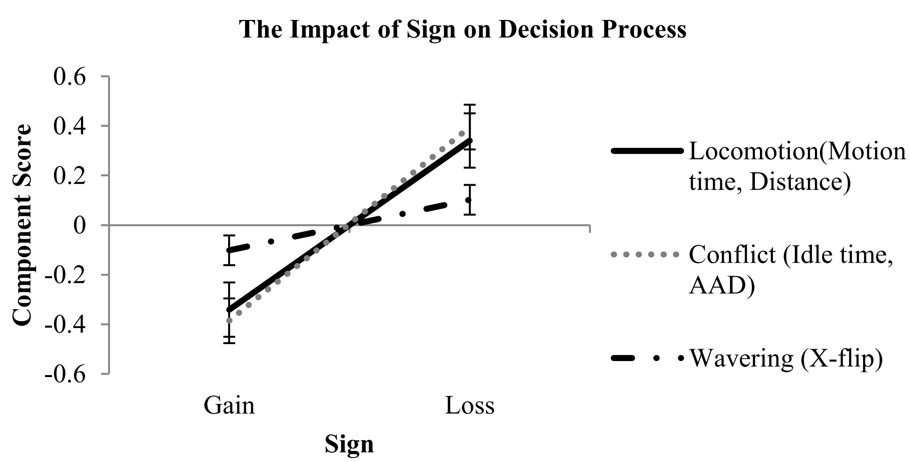

Figure 3. Mean component scores varying as a function of the sign of the payoffs.

The Process measures conditional on final choice (H3). H3 also expects to find that choosing the long-term advantageous options (later larger option in the gain context, and sooner smaller option in the loss context) produces more conflict and uncertainty. This is because when pursuing the long-term benefit, people have to inhibit the temptation of the short-term benefit (Dshemuchadse et al, 2013). This is also consistent with results of Cheng, Lu, Han, González-Vallejo, & Sui (2012) who found that in heroin-dependent patients, those who exhibited a weaker inhibitory ability (as measured by Go/No-go task) were more likely to choose the short-term benefit option in both gain and loss contexts.

In gamble choice (for non-dominant options), it is hypothesized that selecting the riskier gain leads to more conflict and uncertainty than selecting the safer gain. In the loss context, choosing the safer loss is accompanied with a higher level of conflict and uncertainty. That is, greater conflict relates to going against the base tendencies as predicted by prospect theory (people are generally risk averse toward gains but risk seeking toward losses). The prediction would replicate the pattern (Figure 2) that was found in Koop & Johnson (2013).

Numeracy and action dynamics (H4). Numeracy deals with the ability to process numerical information and it is hypothesized that participants with higher numerate ability tend to display a shorter response time (particularly Idle time) as they are better at processing numerical information. The predicted relationship between numeracy and Idle time would further help to clarify the extent to which Idle time measures thinking activity.

Previous studies in medical judgment (e.g., judging the risk of a type of cancer based on probability) and math education have found that numeracy is associated with emotion. That is, adults and kids who were not good at numeracy reported that they experienced negative emotion when they were coping with numerical information (Schapira et al, 2008; Whyte & Anthony, 2012). Thus, if low numerate people are less capable of processing choice information, they may encounter more negative emotion in the loss domain, which raises the internal experience of conflict. Hence, it is predicted that numeracy is negatively related to the Conflict component.

Experiment 1 Methods

Participants. Fifty-one college students (thirty-six females) participated in the study for course credit. Two participants failed to complete the study (voluntarily turned off the choice program and left the study) and hence were removed from the analyses. In Cheng & González-Vallejo (2015), with $n = 43$, the power was .99 and .85 when testing the Conflict and Wavering components' ability to capture the gain-loss manipulation, as shown in Figure 3. Hence, the current sample size is sufficient to meet the power requirement to detect the patterns described in the hypotheses.

Materials and stimuli. Each participant completed a numeracy scale (Weller, Dieckmann, Tusler, Mertz, Burns, & Peters (2013) and a locomotion scale (Kruglanski et al. (2000). The numeracy scale contains eight items (see Appendix A), and has shown good reliability in previous work (Cronbach’s $\alpha = .71$, as reported in Weller et al, 2013). The scale aims to test people's ability to process numerical information, such as estimating probability and making basic algebra calculation. A sample question is "In the

BIG BUCKS LOTTERY, the chances of winning a $10.00 prize are 1%. What is your best guess about how many people would win a $10.00 prize if 1,000 people each buy a single ticket from BIG BUCKS?"

The locomotion scale was adopted from a previous studies which defined locomotion as "*self-regulation concerned with movement from state to state … and maintain goal-related movement in a straightforward and direct manner*" (Kruglanski et al, 2000, p794). As participants moved the cursor to select the options they preferred, the movement might be correlated with the locomotion scale. The scale contains 12 items found in Appendix A with Cronbach's α ranged from .78 to .85 in a series of samples tested in Kruglanski et al. (2000).

For the choice tasks, each participant completed an intertemporal and a gamble choice task. In both tasks, the choice pairs were divided into two categories: pairs with a dominant option, and pairs with no dominant option. There were 15 pairs with a dominant option[5], and 40 pairs with no dominant option, the experimental pairs.

All choice pairs were created via *d*-level, a stimuli based metric from the Proportional Difference Model which indexes the relative advantage of one option over the other (González-Vallejo, 2002). Using this approach to create choice pairs has been successfully carried out in studies of intertemporal, gamble, consumer and health choices (González-Vallejo, 2002; González-Vallejo, Reid, &Schiltz, 2003; González -Vallejo & Reid, 2006;González-Vallejo, Harman, Mullet, & Muñoz Sastre, 2012).

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[5] Given the nature of the dominant option, participants were highly likely to choose it without any difficulty. Hence, 15 trials were sufficient to generate the baseline level of conflict and uncertainty.

In all tasks, including the following two experiments, for experimental choice pairs, the study adopted four different *d*-levels, ranging from -.3 to +.2. These *d*-levels specify different trade-off of advantages and disadvantages creating stimuli that can produce varying preference levels within and across individuals. The *d*-levels used in this study were similar to the ones used in previous studies. Thus, these *d*-levels allowed that the attractiveness of the options varied across choice pairs, and prevented that participants always (or in most cases) chose one option over the other. In contrast, for choice pairs with the dominant option, *d*-level ranged from .5 to .6. Doing so ensured that one option has a clear advantage in both dimensions.

In the intertemporal choice task, participants made choices between a sooner smaller payoff and a later larger one. All choice pairs are found in Table B1 in Appendix B. There were forty experimental choice pairs without a dominant option. The amount and the delay varied across different option pairs. For the sooner smaller option (SS), the magnitude ranged from $28 to $490, with a mean of $205 and a standard deviation of $106; the delay ranged from 4 to 70 days, with a mean of 26 and a standard deviation of 15. For the later larger option (LL), the magnitude ranged from $50 to $900, with a mean of $382 and a standard deviation of $188. The delay ranged from 15 to 120 days, with a mean of 51 and a standard deviation of 23. The gain context and the loss context had the exactly the same attribute magnitude. The only difference was the sign of the payoff.

In the gamble choice task, participants made forty choices between a safer smaller payoff and a riskier larger one. Specific choice pairs are found in Table B2 in Appendix B. For the safer smaller payoff, the magnitude ranged from $46 to $775, with a mean of

$279 and a standard deviation of $178. The probability ranged from .10 to .90, with a mean of .48 and a standard deviation of .23. For the riskier larger option, the magnitude ranged from $100 to $850, with a mean of $438 and a standard deviation of $195. The probability ranged from .04 to .70, with a mean of .26 and a standard deviation of .15. Similar to the intertemporal choice task, the only difference between the gain and loss contexts was the sign of the payoff.

The sequences (created randomly) of choice pairs in Table B1 and Table B2 in Appendix B were adopted in the experiment. The instruction words for each task are presented below.

Intertemporal choice task*:* Decisions dealing with payoff and time are important. For example, a recent report from Wall Street Journal stated that employees needed to make a choice between two types of pensions: either receive an immediate lump sum payment, or receive a larger amount which will be gradually paid for more than a decade. You may also consider how to pay off the tuition debt: the incurred interests are related to how long a student will pay off his/her debt. You will make such choices in the following experiment, and please choose the option based on your preference.

Gamble choice task: Decisions are often accompanied with risk. When we make an investment, we need to consider the probability of gain as well as loss. As an example, government bonds are safer but generate small profits; whereas cooperate bonds are riskier by may bring more profits. In the following experiment you will make choices between a riskier gain(loss) and a safe gain(loss), and please choose the option based on your preference.

Trajectory tracking program. The program displayed in Figure 1 was used. All stimuli (including the following experiments) were presented on a 17 inch screen with a resolution of 1280 * 1024 pixels. The computer program that tracked mouse trajectory was developed in Matlab 2011a (Mathworks Inc), and was run on a Windows 7 desktop. Participants used a Dell Wheel Wired Mouse to complete the choice task. The position of the options (sooner option vs. later option in intertemporal choice; safer option vs. riskier option in gamble choice) was counterbalanced along the top left and right sides of the screen. Participants had the opportunity to practice before engaging in the formal trials. The measures of Idle time, Motion, Distance, X-flip and AAD were obtained and analyzed.

Self-reported decision experiences. In order to test the validity of the manipulations, and derived components, after completing choices in each context (e.g., loss context, more-similar context), participants completed the following four 9-point Likert scales:

1. How difficult were the choices that you just made? Please rate between 1 = not at all difficult to 9 = extremely difficult.
2. How confident were you when making the choices? Please rate between 1 = not confident at all to 9 = very confident.
3. How conflicted did you feel when making choice? Please rate between 1 = not at all conflicted to 9 = extremely conflicted.
4. How satisfied are you with the choices you made? Please rate between 1 = not at all satisfied to 9 = extremely satisfied.

Procedure. Each participant completed the experiment individually in a cubicle. The numeracy and locomotion scales were completed prior to the choice tasks. The sequence of the choice tasks (gambles vs. intertemporal choices) was randomly determined across the participants. Both the task and the gain-loss manipulation were within-subjects factors, and thus each participant completed choices in all four conditions: gain condition in the intertemporal choice task, loss condition in the intertemporal choice task, gain condition in the gamble choice task, and loss condition in the gamble choice task. Within each task, the sequence of gain and loss conditions were counterbalanced. After completing all choices in one condition (e.g., after the 55 trials of intertemporal decisions with gains), participants were asked to complete the four Likert scales of decision experiences. Then participants took a break. The break lasted at least 30 seconds. After completing all choices and decision experience scales, the experiment was complete and participants were debriefed.

Data analysis. As was done in Koop & Johnson (2013) and Cheng & González-Vallejo (2015), the (x, y) coordinate positions of the mouse were recorded at a rate of 100HZ (same across all three experiments). In each single trial, the trajectory program recorded which option was chosen, and the value for each measure during the trial (i.e., each trial gave the measures of ADD, X-flips, Idle time, Motion time, Distance). As done in the previous studies by of Koop & Johnson, Dshemuchadse et al (2013), and Cheng & González-Vallejo, the average of the dynamic measures were computed across trials within the experimental conditions. Thus, in the intertemporal choice task, each participant gave six mean values: one for the sooner smaller gain, one for the later larger gain, one for the sooner smaller loss, one for the later larger loss, and two for the dominant option in both gain and loss contexts. Similarly, in the gamble choice task, each participant also gave six mean values: one for the safer smaller gain, one for the riskier larger gain, one for safer smaller loss, and one for the riskier larger loss, and two for the dominant option in both gain and loss contexts.

Before running the analyses, natural-log was use to transform Idle and Motion times to ensure normality. In addition, outlying observations were identified with a three standard deviations below or beyond the mean as the criterion. Three participants in the intertemporal choice task showed outliers in Idle time, Motion time, Distance, and AAD. In addition, two of them also chose the non-dominant option in 19 out of 30 times when the dominant option was available (the manipulation of dominance was successful in the rest of participants, see analyses below). Therefore, these three participants were removed from the analyses in the intertemporal choice task. In the gamble choice task, one person yielded outliers in all measures except X-flip. Thus, this person was removed from the analyses in the gamble choice task. It is noted that this participant was also an outlier in the intertemporal choice task. Thus, with the removal of two participants in the intertemporal choice task, and one participant from both the intertemporal and choice tasks, the sample sizes were 46 and 48 in the intertemporal and gamble choice tasks, respectively.

Experiment 1 Results

Choice preference and manipulation check. The effect of dominance was checked before further analyses. Participants were supposed to choose the dominant option when it was available. Additionally, the mean values of action dynamics were expected to be smaller when choosing the dominant option than when choosing the other options. Table 4 shows the mean frequencies of choosing different option in different contexts. Table 5 displays the mean values of action dynamic measures when choosing different options in both gain and loss contexts. In the intertemporal choice task, in each context, across 15 choice pairs in which a dominant option was available, only two participants each failed to select the dominant option in two trials. Hence, as shown in Table 4, the mean frequency of choosing the dominant option was 14.96 in each context. In the gamble choice task, all participants chose the dominant option when it was available in both contexts. Thus, the mean frequency of selecting the dominant option was 15 in each context in the gamble choice task. Additionally, as shown in Table 5, in both tasks, when compared to choosing the other options, selecting the dominant option led to significantly smaller mean values in all of the dynamic measures in both gain and loss contexts. Further, as expected, the mean values of the measures when choosing the dominant option remained constant between the gain and loss contexts. More detailed testing results regarding individual measure analyses and dominance effect can be found in Appendix C.

In intertemporal choice, the sign effect refers to the pattern that participants show greater preference toward the long-term advantageous option in the loss context (sooner smaller loss) than in the gain context (later larger gain). Table 4 shows the frequencies of choosing different options in both gain and loss contexts in both tasks. A 2 (sign, gain vs. loss) * 2 (choice, sooner option vs. delayed option) repeated-measures ANOVA was performed on choice frequency, with sign and choice as within-subjects factors. A significant interaction was revealed between sign and choice, $F(1,45) = 4.59$, $p = .038$, partial $\eta^2 = .09$. The main effect for choice was significant, $F(1,45) = 75.62$, $p < .001$, partial $\eta^2 = .63$. The main effect for sign was not significant, $F(1,45) = 0$, $p = 1$ partial $\eta^2 = 0$. Simple tests were performed to unpack the interaction. It was found that participants chose the sooner smaller loss (mean frequency = 21.72 out of 40, 54.3%) more frequently than the later lager gain (mean frequency = 17.07 out of 40, 42.7%), $F(1,45) = 4.59$, $p = .038$, partial $\eta^2 = .09$.

In terms of gamble choices, prospect theory states that people are risk averse in the gain domain whereas they are risk seeking in the loss domain (Tversky & Kahnemann, 1991). Hence, participants were expected to show stronger preference toward the riskier option in the loss context than in the gain context. A 2 (sign, gain vs. loss) * 2 (choice, riskier option vs. safer option) repeated-measures ANOVA was performed on choice frequency, with sign and choice as within-subjects factors. A significant interaction was revealed between sign and choice, $F(1,47) = 43.57$, $p < .001$, partial $\eta^2 = .48$. The main effect for choice was significant, $F(1,47) = 80.48$, $p < .001$, partial $\eta^2 = .63$. The main effect for sign was not significant, $F(1,47) = 0$, $p = .1$ partial $\eta^2 = 0$. Simple tests were performed to unpack the interaction. The riskier option was chosen more frequently in the loss condition (mean frequency = 18.19 out of 40, 45.5%) than in the gain condition (mean frequency = 13.48 out of 40, 33.7%), $F(1,47) = 43.57$, $p < .001$, partial $\eta^2 = .48$.

Table 4

Mean frequencies of choosing different options in gain and loss contexts in Experiment 1

Task	Option	Gain	Loss
Intertemporal	Sooner Smaller	22.94 (.36)	21.72 (.42)
	Later Larger	17.07 (.36)	18.28 (.42)
	Dominant	14. 96 (.03)	14.96 (.03)
Gamble	Riskier	13.48 (.54)	18.19 (.63)
	Safer	26.52 (.54)	21.82 (.63)
	Dominant	15 (0)	15 (0)

Note. Numbers in parentheses are standard errors. For soon and later options in the intertemporal choice task, and riskier and safer options in the gamble choice task, they are out of 40 trials. [6] For the dominant option in both task, it is out of 15 trials.

[6] Note that because choosing the SS and LL options are complementary events within a context, the standard errors of the mean selections must be the same. The standard errors for the mean selection of the dominance option is the same as the number of violations were exactly the same in both contexts as earlier described.

Table 5

Mean of each measure when choosing different options (including the dominant option) in each context in Experiment 1

Task	Condition	Idle	Motion	Distance	X-flip	AAD
Intertemporal	Gain					
	Sooner	4.37 (.06)	2.10 (.06)	33.74 (.76)	4.00 (.10)	2.98 (.18)
	Later	5.07 (.09)	2.45 (.05)	37.90 (.85)	4.30 (.12)	4.23 (.26)
	Domi	1.81 (.02)	.71 (.006)	17.56 (.05)	.11 (.01)	.81 (.009)
	Loss					
	Sooner	7.10 (.22)	2.80 (.06)	43.05 (.83)	4.41 (.11)	5.32 (.19)
	Later	5.82 (.21)	2.28 (.06)	36.50 (.67)	4.22 (.10)	4.32 (.18)
	Domi	1.76 (.02)	.70 (.007)	17.51 (.05)	.13 (.01)	.80 (.01)
Gamble	Gain					
	Riskier	5.16 (.13)	2.15 (.06)	36.13 (.64)	3.32 (.06)	5.02 (.15)
	Safer	4.82 (.09)	1.96 (.04)	32.47 (.55)	3.14 (.10)	4.55 (.12)
	Domi	1.52 (.007)	.83 (.009)	18.36 (.07)	.14 (.01)	.77 (.008)
	Loss					
	Riskier	6.00 (.12)	2.21 (.04)	37.06 (.69)	3.60 (.08)	5.74 (.16)
	Safer	6.78 (.14)	2.43 (.06)	39.22 (.85)	3.87 (.14)	6.60 (.20)
	Domi	1.51 (.009)	.81 (.01)	18.45 (.06)	.13 (.02)	.79 (.02)

Note. Numbers in parentheses are standard errors. Units for Idle time and Motion time were seconds. Units for Distance and AAD were centimeters. The values for Idle and Motion times in this table were not natural-log transformed. Domi: the dominant option.

Table 6 shows the self-reported decision experiences, including the experienced decision difficulty and conflict, and self-report of confidence and satisfaction with their decisions. In both tasks, in the loss context than in the gain context, participants reported that they felt greater difficulty and conflict when making decisions, and were less confident. In addition, in the gamble choice task, participants were also less satisfied about their decisions in the loss context.

Taken together, the study replicated the choice preference pattern between the gain and loss contexts in both tasks. The dominance effect was revealed. Participants met more difficulty in the loss domain than in the gain domain. Hence, the manipulation of sign and dominance were successful. Hypotheses 1 to 4 were tested in the following sections.

Table 6

Self-reported experiences in gain and loss contexts in Experiment 1

Task	Self-report measures	Gain	Loss	Paired *t*-test	Conflict-Gain	Wavering-Gain	Locomotion-Gain	Conflict-Loss	Wavering-Loss	Locomotion-Loss
Inter-temporal	Difficulty	3.65 (.13)	5.50 (.16)	-8.50***	.30	.07	.28	.05	-.21	.03
	Conflict	3.41 (.12)	6.02 (.22)	-11.81***	.30	-.11	-.09	.39	-.06	-.23
	Confidence	6.80 (.18)	5.76 (.16)	4.45***	.06	.10	.10	-.26	-.07	.04
	Satisfactory	6.85 (.20)	6.57 (.23)	.90	.26	.02	-.18	-.02	-.09	-.08
Gamble	Difficulty	3.81 (.13)	5.25 (.17)	-6.29***	.14	-.10	-.08	.10	.23	-.07
	Conflict	4.02 (.16)	5.31 (.22)	-5.15***	.26	-.10	.04	.004	-.20	-.02
	Confidence	7.08 (.13)	5.52 (.17)	8.11***	.22	-.20	.03	.02	-.04	.05
	Satisfactory	7.04 (.13)	5.40 (.14)	9.55***	.12	-.17	.15	.28	.06	.08

Note. Numbers in parentheses are standard errors. For paired *t*-test, the degrees of freedom were 45 and 47 for the intertemporal choice task and gamble choice task, respectively. ***: $p < .001$. The *p*-values in Table 6 were subject to Bonferroni α correction, with $p = .004$ (12 correlations per context per task) as the cut-off value.

Testing H1: structure of action dynamic measures. H1 stated that in both choice tasks, a three-component structure would result from the action dynamic measures, replicating and extending the findings in Cheng & González-Vallejo (2015). More specifically, the psychological states of conflict (Idle and AAD) and wavering (X-flip) could be differentiated.

Table 7 displays the correlations among the five measures in the intertemporal choice task. It was found that Distance was highly related to Motion time, X-flip was not related to any other measures, and AAD correlated with Idle time, Distance, and Motion time. The relationship between AAD and Distance or Motion time are in part due to the geometric characteristics (i.e., greater absolute distance implies more distance and more time to move). However, the relationship between AAD and Idle time, we suggest, highlights the psychological meanings of both measures: the competition between the two options and the thinking process that dealt with that competition. Given that multiple measures were inter-related, PCA was particularly useful to depict the structure of the components. In other words, with PCA, we were able to determine which measures should be grouped together in the presence of the other measures.

PCA was run with data based on all participants in both gains and loss contexts differentiating when participants selected the sooner option, or the delayed option. In the intertemporal choice task PCA included 5 measures for each of 46 participants in the 4 conditions (gain-sooner, gain-later, loss-sooner, loss-later). Eighty percent of explained variance was employed as the cut-off value to determine the components (SAS manual; King & Jackson, 1999). Table 8 shows the PCA results with a Varimax orthogonal rotation for the intertemporal choice task. The first three components accounted for 82.91% of variance. The first component included Distance and Motion time. The second component included AAD and Idle time. The third component only contained X-flip. Hence, the pattern resembled the findings in Cheng & González-Vallejo (2015).

Table 7

Correlations among decision process measures

	AAD	X-flip	Distance	Idle Time	Motion Time
AAD	----	.001	.35	.38	.32
X-flip		----	.07	.07	.01
Distance			----	.35	.75
Idle Time				----	.29

Table 8

Principal component analysis for decision process measures in intertemporal choice task

	Rotated Components			Communalities
	1	2	3	
AAD	.21	**.80**	-.08	.69
X-flip	.02	.02	**.99**	.99
Distance	**.90**	.23	.06	.87
Idle time	.16	**.82**	.11	.71
Motion time	**.93**	.17	-.02	.88
Eigenvalues	2.26	1.0	.89	
Variances accounted (%)	45.10	20.10	17.71	

Note. Loading greater than .6 was considered as significant (Comrey & Lee, 1992).

A similar result was obtained in the gamble choice task. Table 9 shows the correlation matrix among five measures in the gamble choice task. It was found that X-flip was not related to any other measures. AAD was related to Distance, Idle and Motion times, however, its relationship with Idle time was the strongest. Not surprisingly, Motion time was related to Distance.

In terms of PCA, a three-component structure was observed in the gamble choice task, with the first three components explaining 84.40% of the variance. The PCA analyses was done on 5 measures for each of 48 participants in the 4 conditions (gain-riskier, gain-safer, loss-riskier, loss-safer). Table 10 displays the PCA results in the gamble choice task. Following Cheng & González-Vallejo (2015), the component encompassing Idle time and AAD was termed Conflict, the component with Distance and Motion time was labeled Locomotion, and the component with X-flip was termed Wavering.

Table 9

Correlations among Decision Process Measures

	AAD	X-flip	Distance	Idle Time	Motion Time
AAD	----	.07	.42	.60	.31
X-flip		----	.09	.20	.05
Distance			----	.46	.56
Idle Time				----	.28

Table 10

Principal component analysis for decision process measures in gamble choice task

	Rotated Components			Communalities
	1	2	3	
AAD	**.90**	.19	-.04	.81
X-flip	.08	.03	**.99**	.99
Distance	.37	**.78**	.04	.76
Idle time	**.85**	.21	.18	.80
Motion time	.10	**.92**	.01	.85
Eigenvalues	2.36	1.01	.84	
Variances accounted (%)	47.25	20.42	16.73	

Note. Loading greater than .6 was considered as significant.

In both tasks, component scores were obtained for each person in each context when selecting each type of the options. Correlations were made between the average component scores in a given task (e.g., intertemporal choices in gains) and the self-reported decision experiences in that task. The self-reported measures included the ratings of difficulty, conflict, confidence and satisfaction, resulting in a total of twelve correlations (4 ratings correlated with 3 component scores). Bonferroni α correction was adopted with p = .004 as the cut-off value for significance testing of these correlations. None of the tests was significant: the largest correlation was found between the Conflict component and the conflict experience rating in the intertemporal choice task, $r(44) = .39$, $p = .008$.

In Experiment 1, the Cronbach's α of the locomotion scale was .603 across all 51 participants.[7] The average score was 3.93 (out of 6). The correlation between the

[7] Although two participants did not finish the choice tasks, they completed the numeracy and locomotion scales. Those who showed outliers in action dynamic measures also

locomotion component (averaged across gain and loss contexts) and the locomotion score of each person resulted in no significant results in either the intertemporal or gamble task: $r(44) = -.04$, $p = .802$ for the intertemporal choice task; $r(46) = -.17$, $p = .247$ for the gamble choice task.

Testing H2 and H3: effect of sign on decision process and decision process conditional on final choice. H2 and H3 predicted greater conflict and uncertainty in losses relative to gains. Furthermore, Conflict was predicted to be more sensitive to the gain-loss contextual variation, when compared to Wavering. In terms of the relationship between what was selected and the components, in the intertemporal choice task, choosing the long-term advantageous option (later larger gain and sooner smaller loss) leads to greater conflict and uncertainty. In the gamble choice task, choosing the riskier gain and safer loss leads to greater conflict and uncertainty.

With PCA, in both tasks, component scores were obtained for each person in each context when choosing each type of the options. To compare measures' capacity to capture the sign effect and what was selected, a 3 (three components: Conflict, Wavering, Locomotion) * 2 (sign: gain, loss) * 2 (selected option: sooner option and later option in the intertemporal choice task; riskier option and safer option in the gamble choice task) repeated-measures ANOVA was performed on component scores in each task, with

completed these two scales. Further, their responses in scales appeared to be normal. Thus, when computing Cronbach's α and average score of the scales, all participants were included. The same approach was also adopted in Experiments 2 and 3. Average correct response rate and Cronbach's α changed little if these participants were eliminated.

component, sign and selected option as within-subjects factors. Follow-up simple tests (if applicable) were conducted to test both H2 and H3 in each task, as shown below.

Effect of sign. In the intertemporal choice task, there was a significant interaction between sign and selected option, $F(2,44) = 112.78$, $p < .001$, partial $\eta 2 = .72$, *Wilks' Λ* = .29. There was a significant interaction between sign and component, $F(2,44) = 10.26$, $p < .001$, partial $\eta 2 = .32$, *Wilks' Λ* = .68. The main effect of sign was significant, $F(1,45) = 72.07$, $p < .001$, partial $\eta 2 = .62$, *Wilks' Λ* = .38. No other interactions or main effects were significant. Simple tests were carried out to understand the interaction.

When testing components' variation between the gain and loss contexts (i.e., the interaction between sign and component), Conflict showed an effect of context being greater in losses (mean Conflict in losses = .56; mean Conflict in gain = -.56. These means were computed by collapsing across selected options given that selected option was not involved in the interaction between sign and component), $F(1,45) = 106.0$, $p < .001$, partial $\eta 2 =.70$; whereas mean Wavering did not differ between the contexts (mean Wavering = .11 in gains; mean Wavering = -.11 in losses), $F(1,45) = 2.25$, $p =.140$, partial $\eta 2 =.05$. Locomotion was also larger in the loss than in the gain contexts (mean Locomotion = .20 in losses; mean Locomotion = -.20 in gains), $F(1,45) = 9.45$, $p = .004$, partial $\eta 2 =.17$. Further, Conflict showed a larger mean difference (between the two contexts, mean difference = 1.12) than did Locomotion (mean difference = .40), $F(1,45) = 12.23$, $p = .001$, partial $\eta 2 = .21$. Figure 4 depicts the components' variation between the gain and loss contexts in this task.

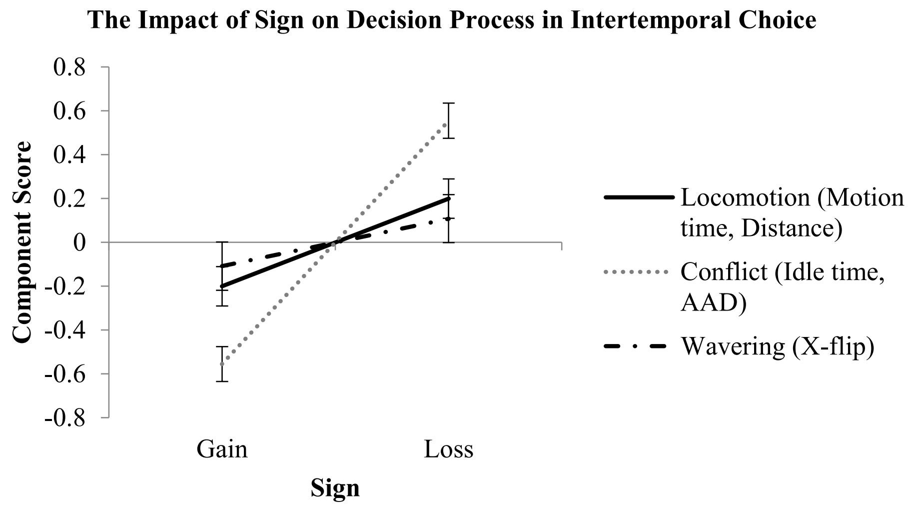


Figure 4. The impact of sign on decision process in the intertemporal choice task.

A similar repeated-measures ANOVA was performed in the gamble choice task, with the component scores as the dependent variable. There was a significant interaction between sign and selected option, $F(1,47) = 59.38$, $p < .001$, partial $\eta 2 = .56$, *Wilks' Λ* = .44. There was a significant interaction between sign and component, $F(2,46) = 4.89$, $p = .01$, partial $\eta 2 = .18$, *Wilks' Λ* = .83. The main effect of sign was significant, $F(1,47) = 181.4$, $p < .001$, partial $\eta 2 = .79$, *Wilks' Λ* = .21. No other interactions or main effects were significant.

In terms of the interaction between sign and component, mean Conflict was larger in the loss than in the gain contexts when collapsing across the selected option factor (mean Conflict = .57 in losses; mean Conflict = -.57 in gains), $F(1,47) = 85.56$, $p < .001$, partial $\eta 2 = .65$; so was Wavering (mean Wavering = .30 in losses; mean Wavering = -.30 in gains), $F(1,47) = 25.83$, $p < .001$, partial $\eta 2 = .36$. Locomotion also showed this pattern (mean Locomotion = .24 in losses; mean Locomotion = -.24 in gains), $F(1,47) = 11.95$, $p = .001$, partial $\eta 2 = .20$. Moreover, Conflict showed a larger mean difference (between the gain and loss contexts, mean difference = 1.04) than did Wavering (mean difference = .60), $F(1,47) = 7.93$, $p = .007$, partial $\eta 2 = .14$. Conflict also showed a larger variation than did Locomotion (mean difference for Locomotion = .48), $F(1,47) = 8.44$, $p = .006$, partial $\eta 2 = .15$. No difference in the mean difference was detected between Locomotion and Wavering, $F(1,47) = .36$, $p =.553$, , partial $\eta 2 = .008$. Figure 5 shows the impact of sign on decision process in the gamble choice task.

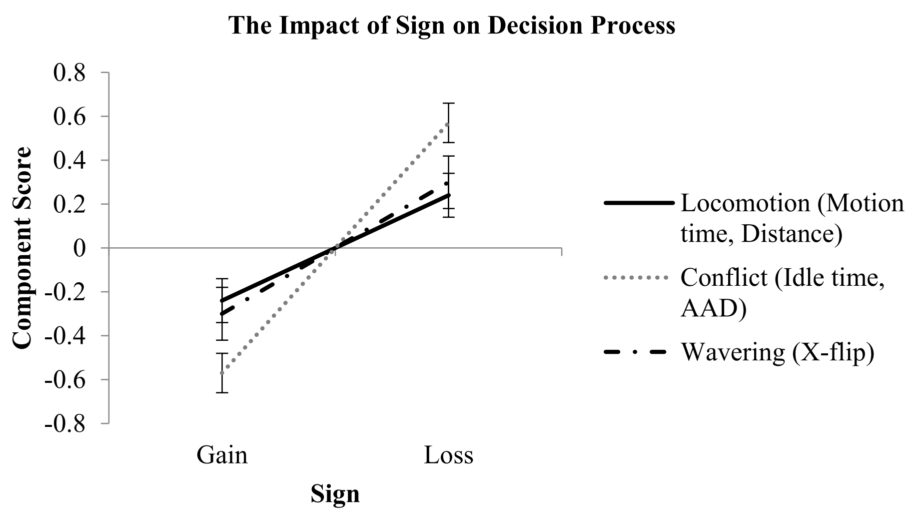


Figure 5. The impact of sign on decision process in the gamble choice task.

Process conditional on final choice. As reported above, there was a significant interaction between sign and selected option in the intertemporal choice task. Simple tests showed that choosing the delayed option led to higher means across all three components in the gain context (means for Conflict, Wavering and Locomotion when choosing the later gain were -.25, .06, and .12, respectively; means for Conflict, Wavering and Locomotion when choosing the sooner gain were -.86, -.28, and -.52, respectively), $F(1,45) = 52.06$, $p < .001$, partial $\eta 2 = .54$ when collapsing across three components (given no interaction was found between component and selected option). In the loss context, choosing the sooner option resulted in higher means across all three components (means for Conflict, Wavering and Locomotion when choosing the sooner loss were .90, .23 and .71, respectively; means for Conflict, Wavering and Locomotion when choosing the later loss were .21, -.01 and -.31, respectively), $F(1,45) = 63.70$, $p < .001$, partial $\eta 2$ =.59 when collapsing across three components.

In the gamble choice task, a significant interaction was found between sign and component from the ANOVA described above. It was found that in the gain context, choosing the riskier option led to greater Conflict, Wavering and Locomotion (means for Conflict, Wavering and Locomotion when choosing the riskier gain were -.44, -.20 and .05, respectively; means for Conflict, Wavering and Locomotion when choosing the safer gain were -.70, -.39 and -.20, respectively), $F(1,47) = 29.59$, $p < .001$, partial $\eta 2$ = .39, averaging across components. In the loss context, choosing the safer option led to greater means (means for Conflict, Wavering and Locomotion when choosing the safer loss were .88, .44 and .44, respectively; means for Conflict, Wavering and Locomotion when choosing the riskier loss were .25, .15, and .05, respectively), $F(1,47) = 30.09$, $p < .001$, partial $\eta 2$ =.39 when collapsing across components. We note that in gains, the mean components were smaller than in losses (the main effect of sign) demonstrating that difficulty arises more clearly in the loss domain as expected.

Taken together, H2 and H3 received support: (1) in the intertemporal choice task, making decisions in the loss domain led to greater Conflict, but not Wavering. In the gamble choice task, making decisions in the loss domain led to greater Conflict and Wavering. However, Conflict was better at capturing the contextual variation between gains and losses in this task. Hence, Conflict was more sensitive to the gain-loss variation, and was the major source for decision difficulty in the loss context. (2) Choosing the long-term advantageous option in the intertemporal choice task; choosing the riskier option over the safer option in the gain domain, and choosing the safer option over the riskier in the loss domain led to greater Conflict and Wavering.

In addition to testing the components, the effects of sign and what was selected were also examined at the individual measure level. The variation in the individual measures consistent with the variation in the components (e.g., longer Idle time in the loss context than in the gain context in both tasks). Descriptive statistics of individual measures are found in Appendix C.

Testing H4: role of numeracy in decision process. H4 predicted that when choosing the dominant option, the process was not affected by numeracy because the decision was easy to make. By contrast, when the dominant option was not available, numeracy should relate negatively to Idle time and the Conflict component.

The average correct response rate of the numeracy scale was 51.5% across all 51 participants. The Cronbach's α was .546 which is relatively low. In each task, correlations were made between numeracy and the means of the five dynamic measures (obtained by averaging across all conditions) for the experimental choice pairs (i.e., no dominant option was available). With $p = .01$ as the cut-off value after Bonferroni correction, across all participants, numeracy was negatively associated with mean Idle time (natural-log transformed), $r(44) = -.49$, $p < .001$. As expected, numeracy was not related to Idle time when choosing the dominant option, $r(44) = .08$, $p = .602$. In terms of the component scores, with $p = .017$ as the cut-off value, numeracy was negatively related to mean Conflict (when collapsing across all conditions), $r(44) = -.46$, $p = .001$. Numeracy was not related to any other measure or component regardless of whether the dominant option was available, all *p*-values > .05.

In the gamble task, with $p = .01$ as the cut-off value, when trade-offs had to be made, the relationship between mean Idle time and numeracy, $r(46) = -.53$, $p < .001$. Over the choice pairs where a dominant option was available, numeracy was not related to Idle time, $r(46) = -.18$, $p = .225$. For components, with $p = .017$ as the cut-off value, the relationship between numeracy and mean Conflict was close but failed to reach the significance level, $r(46) = -.33$, $p = .021$. Numeracy was not related to any other measure or component regardless of whether the dominant option was available.

Experiment 1 Discussion

Experiment 1 had several major findings. Consistent with Cheng & González-Vallejo (2015), in both intertemporal choice and gamble choice tasks, the five action dynamic measures could be grouped into three distinct components: Conflict, Wavering, and Locomotion. The Conflict component contained Idle time and AAD, and hence captured the processes of thinking and solving competition between the alternatives. The Wavering component consist of X-flips. Most importantly, more directional flips did not led to a clear increase of travelled distance, thus, the Wavering component indexed small directional flips between the options, and resembled the feeling of uncertainty. The psychological meaning of the Locomotion component is not specific because it deals with the overall movement function; in general, greater distance and time to cover that distance was expected to also related to the greater deviations from a straight path (as measured by AAD). However, the AAD was movement specific, and in combination with Idle time, it appeared to tap into a specific spatial/temporal pattern that reflected conflict. Hence, the PCA results demonstrated that different action dynamic measures captured different aspects of decision process. Moreover, by examining the variation of the components, the decision process and decision difficulty in different situations could be depicted.

First, in the intertemporal choice task, participants displayed more conflict but not more wavering in the loss context than in the gain context. In the gamble choice task, although participants showed more conflict and uncertainty in the loss than in the gain context, conflict was more sensitive to the gain-loss variation. Thus, the results implied that the experience of conflict, rather than uncertainty, was the major source of decision difficulty in the loss domain. In past studies the sign effect referred to the choice preference variation between the gain and loss contexts. The present study further extended its meaning to the process domain: the experience of conflict and uncertainty vary as a function of the sign of the context, but the experience of conflict is most salient in losses than in gains.

Second, participants exhibited greater conflict and uncertainty when selecting the long-term advantageous options in the intertemporal choice task. The findings supported the notion that choosing the long-term advantageous options took more cognitive effort in order to inhibit the temptation of the short-term benefits (Dshemuchadse et al, 2013). Such a finding helped to explain the myopic choices in the substance abusers, as they had a weaker inhibitory control ability and were thus less likely to inhibit the short-sighted tendency (Cheng et al, 2012).

From the choice preference perspective, the prospect theory contends that people are risk-averse in the gain domain and risk-averse in the loss domain. The present study was in line with this notion from the aspect of choice preference. More importantly, it was also found that choosing the riskier gain over safer gain, and choosing the safer loss over the riskier loss resulted in greater conflict and uncertainty. Therefore, the current work further extended the meanings of risk-seeking and risk-averse from the process and experience perspective: when making decisions that go against people's default tendencies, participants experienced more conflict and uncertainty regarding their choices.

The present study also investigated the relationship between numeracy, an internal cognitive ability, and decision process. As earlier discussed, in daily life and lab experiments, options are often expressed with numerical information. In line with the hypothesis, people with poorer numerical ability tended to use longer Idle time to reach the decisions, indicating that they needed more time to process the numerical values. Furthermore, numeracy was also negatively related to the Conflict component, implying that lower numerate participants experienced more competition from the options when they were making choices. In other words, lower numerate people appeared to have a harder time making numerical the trade-offs.

Experiment 1 did not find a reliable relationship between any self-report measure and component, although the self-report measures were able to vary in the expected direction between the gain and loss contexts. One reason might be that action dynamics measured *online* processes when participants were making decisions, whereas self-report measures were obtained after participants completed a series of choices. Additionally, a previous study with intertemporal choice found that traditional psychological scales were not consistently related to behavioral measures, such as choice preference (Reynolds, Ortengren, Richards, & de Wit, 2006). Therefore, action dynamics were able to capture unique psychological and behavioral processes that could not be indexed by traditional self-report measures. This issue would also be tested in the following experiments.

In summary, the first experiment demonstrated that both conflict and uncertainty were the sources of decision difficulty in the loss context, but conflict played a more important role. Furthermore, when making choices against the basic preference tendencies (e.g., immediate gain, and safer gain), the experience of conflict and uncertainty was elevated. Finally, poorer numerical ability was associated with more conflicted experience in the decision process.

Experiment 2

Experiment 2 aimed at testing the relationship between action dynamics and similarity between the options. When options are similar, the situation is more ambiguous because it is more difficult to discriminate one option from the other. Action dynamics have been applied to test the role of similarity and uncertainty in intertemporal choice (Dshemuchadse et al, 2013 with only the measure of curvature; Cheng & González-Vallejo, 2015). This study hopes to generalize the findings to gamble and consumer choices. In other words, the purpose is to better understand the feelings of uncertainty and the situations that give rise to this aspect of difficulty. The intertemporal choice task and gamble choice task are similar to the ones used in Experiment 1. That is, the gain condition in both tasks in Experiment 1 serves as the baseline condition (less-similar condition) in Experiment 2 making results of both experiments comparable. Experiment 2 further creates a more-similar condition to test the role of similarity and uncertainty in both tasks. The manipulation of similarity, as described below, is a within subjects factor.

In McClure et al (2004), the difference of attributes between the options was manipulated in order to create different levels of similarity. Consistently, participants exhibited longer response times when the differences between the options were smaller. The present study adopts a similar approach. In both tasks, similarity was manipulated by reducing the value differences of the options' attributes. Take the intertemporal choice task as an example, the choice of receiving $61 in 19 days vs. receiving $69 in 27 days is a more-similar pair than the choice of receiving $55 in 14 days vs. receiving $75 in 32 days. This is because the differences in the dimensions of money and time between the options is reduced by about 60% from the first to the second pair (the money difference in the first choice pair is $8, and is $20 in the second choice pair). This methodology was adopted to manipulate similarity.

Hypotheses in Experiment 2

Structure of action dynamics (H5). Similar to Experiment 1, in both tasks in Experiment 2, it is hypothesized that the action dynamic measures will be differentiated into the three PC components of Conflict (encompassed of Idle time and AAD), Wavering (including X-flip), and Locomotion (including Distance and Motion time).

The effect of similarity (H6). When facing the experimental choice pairs (i.e., no dominant option is available), it is hypothesized that participants will show more conflict and uncertainty in the more-similar than in the less-similar condition. Most importantly, the Wavering (uncertainty) component is expected to show the greatest variation between the two conditions when compared to other the components.

Process conditional on final choice (H7). It is predicted that choosing the later larger gain in the intertemporal choice task, and choosing the riskier larger gain in the gamble choice task results in more conflict and uncertainty, as shown in Experiment 1.

Numeracy and action dynamics (H8). Similar to Experiment 1, it is hypothesized that higher numerate people are more likely to show shorter Idle time and lower conflict when making choices without the dominant option. By contrast, numeracy has no impact on the process when choosing the dominant option.

Experiment 2 Methods

Participants. Fifty college students (thirty-three females) participated in the study for course credit. Two participants failed to complete (voluntarily turned off the choice program and left the study) the study and were removed from the analyses.

Materials and stimuli. The format of materials and stimuli were similar to those used in Experiment 1.

Trajectory tracking program. The same as that used in Experiment 1.

Choice pairs. Similar to Experiment 1, both experimental choice pairs (40 pairs) and dominant option pairs (15 pairs) were adopted in Experiment 2 in both tasks. For the intertemporal choice and gamble choice tasks, the stimuli in the gain context in Experiment 1 were used as the less-similar condition in Experiment 2. Doing so aimed to replicate the results from Experiment 1 with a different sample of participants.

To construct the more-similar condition, in the intertemporal choice task, the attributes of money and time in the later larger option were reduced by 30% of the attribute differences between the two corresponding options in the less-similar condition. By contrast, the attributes of money and time in the sooner smaller option were increased by 30% of the attribute differences between the two corresponding options in the less-similar condition. Thus, with such a method, the difference in each attribute of each choice pair in the more-similar condition appeared to be closer to each other. For example, in the less-similar condition, the choice pair was receiving $55 in 14 days vs. receiving $75 in 32 days. The money difference between the options was $20 ($75-$55), and the time difference was 18 days (32-14). In the more-similar condition, the money attribute of the later larger option was decreased by 30% of the money difference ($20), and resulted in 75 - $20*30% = $69. Similarly, the time attribute of the later larger option was obtained by subtracting 30% of the time difference (18 days) from original delay, and hence was 27 days (always rounding to the closest whole number). In terms of the sooner smaller option in the more-similar condition, both time and money attributes were increased by 30% of the attribute differences in the less-similar condition. That is, for the money attribute, it was computed as $55 + $20*30% = $61. For the time attribute, it was acquired as 14 days + 30%*18 days = 19 days.

In the gamble choice task, a similar method was used to construct the more-similar condition. That is, in the more-similar condition, the money attribute of the riskier option and the probability of the safer option were reduced by 30% of the corresponding attribute difference acquired from the less-similar condition. By contrast, the money attribute of the safer option and the probability of the riskier option were increased by 30% of the corresponding attribute differences. Thus, the differences in attributes in the more-similar condition were still about 60% smaller than those in the less-similar condition. In the gamble choice task, whole numbers were used for the money attribute, and two decimal places were used for the probability attribute.

Scales and self-reported measures. Numeracy scale, locomotion scale and self-reported experiences (difficulty, conflict, confidence and satisfaction) used in Experiment 1 were also adopted in the second experiment.

Procedures. Each participant completed the experiment individually in a cubicle. Participants completed the numeracy and locomotion scales prior to engaging in the choice tasks. In this experiment, each participant completed two tasks: intertemporal choice task, and gamble choice task. For each participant, the sequence of the tasks was randomly determined before starting of the experiment. The major purpose of this experiment was to test choice behaviors when similarity between the options was manipulated. The manipulation of the similarity was a within-subjects design. That is, each participant completed choices in the less-similar and more-similar contexts (sequence randomly determined). Similar to Experiment 1, dominant options were included in both contexts. Hence, each participant experienced non-dominant choice pairs and dominant choice pairs in both less-similar and more-similar contexts.

Similar to Experiment 1, after completing all choices in one context, participants completed the four self-reported scales regarding decision experiences. Then a break that lasted at least 30 seconds (same with Experiment 1, participants could decide to continue or not after 30 seconds of the break) started. After completing all choices and scales, participants were debriefed before leaving.

Data analysis. Similar to Experiment 1, in both tasks, averages were taken for each measure based on what was chosen and the similarity of the context. That is, each participant gave six values for each measure: 2 (less-similar vs. more-similar) * 3 (three different option types, including the dominant option). Idle and Motion times were transformed with natural-log. Two participants each missed at least 8 out of 15 times when the dominant option was available. Additionally, one of these participant's Idle time was beyond three standard deviations above the mean in both tasks. These two participants were removed from the following analyses. Thus, the sample size was 46 in each task.

Experiment 2 Results

Choice preference and manipulation check. The effect of dominance was first checked. In the intertemporal choice task, across all participants, for the 15 trials in which a dominant option was available, in the less-similar context, one participant failed to select the dominant option in one trial and another participants failed to select this option in two trials. In the more-similar context, two participants each failed to select the dominant option in one trial. Thus, participants selected the dominant option in 99.3% of trials in which this option was available. In the gamble choice task, only one participant failed to choose the dominant option in one trial in the more-similar context when this option was available. The dominant option was selected in all other trials across two contexts. In terms of testing dominance and action dynamic measures, similar to Experiment 1, when making choices when a dominated option was available, all measures showed the smallest mean values when compared the other situations. Additionally, in the dominant condition, all measures remained constant between the less-similar and more-similar contexts in both tasks. Tables 11 and 12 show the mean frequencies and values of action dynamic measures when choosing different options in both less-similar and more-similar contexts. More detailed analyses regarding dominance can be found in Appendix D.

To test the effect of similarity on choice preference, for the intertemporal choice task, a 2 (similarity, less-similar vs. more-similar) * 2 (choice, sooner option vs. delayed option) repeated-measures ANOVA was performed on the frequencies of choosing different options, with similarity and choice as within-subjects factors. The main effect for choice was significant, $F(1,45) = 46.02$, $p < .001$, partial $\eta 2 = .51$. The main effect for similarity was not significant, $F(1,45) = 0$, $p = 1$, partial $\eta 2 = 0$. The interaction between similarity and choice was not significant, $F(1,45) = .26$, $p = .612$, partial $\eta 2 = .006$. Hence, participants' preference toward the sooner option, or the later option was not affected by similarity.

In the gamble choice task, a 2 (similarity, less-similar vs. more similar) * 2 (choice, riskier option vs. safer option) repeated-measures ANOVA was performed on the frequencies of choosing different options, with similarity and choice as within-subjects factors. There was a significant main effect of choice, $F(1, 45) = 137.7$, $p < .001$, partial $\eta 2 = .75$. The main effect of similarity was not significant, $F(1, 45) = 0$, $p = 1$, partial $\eta 2 = 0$. The interaction between similarity and choice was not significant, $F(1, 45) = 1.13$, $p = .293$, partial $\eta 2 = .02$. Therefore, both tasks indicated that similarity had no impact on choice preference

Table 11

Mean frequencies of choosing different options in less-similar and more-similar contexts in Experiment 2

Task	Chosen Option	Less-similar	More-similar
Intertemporal	Sooner Smaller	22.11 (.45)	21.74 (.47)
	Later Larger	17.89 (.45)	18.26 (.47)
	Dominant	14.94 (.05)	14.96 (.03)
Gamble	Riskier	14.44 (.59)	15.37 (.64)
	Safer	25.57 (.59)	24.63 (.64)
	Dominant	15.0 (0)	14.98 (.02)

Note. Numbers in parentheses are standard errors. For soon and later options in the intertemporal choice task, and riskier and safer options in the gamble choice task, they are out of 40 trials. For the dominant option in both task, it is out of 15 trials.

Table 12

Mean of each measure when choosing different options (including the dominant option) in each context in Experiment 2

Task	Condition	Idle	Motion	Distance	X-flip	AAD
Intertemporal	Less-similar					
	Sooner	4.10 (.07)	1.92 (.06)	31.75 (.77)	3.78 (.10)	2.71 (.16)
	Later	4.52 (.08)	2.53 (.07)	40.65 (.99)	4.18 (.12)	3.62 (.24)
	Dominant	1.71 (.02)	.71 (.007)	17.67 (.04)	.11 (.01)	.87 (.009)
	More-similar					
	Sooner	4.21 (.17)	2.18 (.06)	35.64 (.67)	5.09 (.11)	3.30 (.15)
	Later	5.50 (.18)	2.75 (.06)	42.82 (.91)	5.64 (.12)	3.95 (.15)
	Dominant	1.69 (.02)	.72 (.007)	17.96 (.05)	.11 (.01)	.89 (.01)
Gamble	Less-similar					
	Riskier	4.89 (.11)	2.16 (.05)	34.75 (.59)	3.39 (.12)	5.07 (.15)
	Safer	4.39 (.09)	1.86 (.04)	30.10 (.64)	2.95 (.12)	4.25 (.14)
	Dominant	1.74 (.03)	.67 (.006)	17.37 (.05)	.07 (.009)	.79 (.008)
	More-similar					
	Riskier	5.41 (.12)	2.43 (.06)	39.78 (.67)	4.63 (.14)	5.56 (.19)
	Safer	4.99 (.10)	2.21 (.06)	34.84 (.69)	4.18 (.17)	5.02 (.13)
	Dominant	1.70 (.02)	.65 (.006)	17.32 (.05)	.06 (.008)	.78 (.01)

Note. Numbers in parentheses are standard errors. Units for Idle time and Motion time were seconds. Units for Distance and AAD were centimeters. The values for Idle and Motion times in this table were not natural-log transformed.

In terms of self-reported measures, Table 13 displays the ratings of difficulty, conflict, confidence, and satisfaction in each context. In both tasks, in the more-similar context than in the less-similar context, participants reported that they felt greater difficulty when making decisions, and were less confident. In the intertemporal choice task, participants also reported more conflict in the more-similar context. Their satisfaction about the decisions did not vary between the contexts. Therefore, the manipulation of similarity had an impact on decision experience, but not on decision preference.

Table 13

Self-reported experience in less-similar and more-similar contexts in Experiment 2

Task	Self-report measures	Gain	Loss	Paired *t*-test	Conflict-Less	Wavering-Less	Locomotion-Less	Conflict-More	Wavering-More	Locomotion-More
Inter-temporal	Difficulty	3.50 (.18)	6.57 (.16)	-11.59***	.06	-.08	.02	.01	-.02	-.03
	Conflict	3.80 (.17)	5.74 (.20)	-8.52***	.09	-.19	.03	.39	.18	-.27
	Confidence	6.65 (.20)	4.83 (.15)	7.38***	.11	-.06	-.14	.13	-.20	.01
	Satisfactory	5.63 (.22)	5.39 (.25)	.72	.01	-.17	.09	.04	-.06	.06
Gamble	Difficulty	4.20 (.20)	6.28 (.20)	-6.97***	.07	-.27	.18	-.04	-.22	-.03
	Conflict	4.63 (.22)	5.41 (.26)	-2.36	.04	.04	-.07	.23	-.07	.04
	Confidence	6.26 (.16)	4.91 (.23)	4.04***	-.16	-.03	.17	.05	-.17	.07
	Satisfactory	5.50 (.20)	5.35 (.17)	.65	.13	-.07	-.06	.01	.05	.04

Note. Numbers in parentheses are standard errors. ***: $p < .001$. The *p*-values in Table 13 were subject to Bonferroni α correction, with $p = .004$ (12 correlations per context per task) as the cut-off value.

Testing h5: structure of action dynamic measures. H5 proposed a three-component structure of action dynamic measures in both tasks. Tables 14 present the correlation matrix for the intertemporal choice task. Consistent with Experiment 1, the relationship between Distance and Motion time was high. However, the relationship between AAD and Idle time appeared to be smaller than the relationship between AAD and Distance. Nonetheless, as shown in Table 15, with eighty percent of explained variance as the cut-off value, the five measures were again grouped into three components. In total there was 80.64% of variance being explained. Most importantly, Distance and Motion time were grouped together, AAD and Idle time were combined, and X-flip was independent. The results from PCA emphasized its advantage to show a *clean* pattern of the structure. In other words, PCA contributed to understanding the exact relationship between the measures when controlling for other measures.

Table 14

Correlations among decision process measures in intertemporal choice task in Experiment 2

	AAD	X-flip	Distance	Idle Time	Motion Time
AAD	----	.08	.33	.20	.30
X-flip		----	.25	.23	.21
Distance			----	.27	.74
Idle Time				----	.25

Table 15

Principal component analysis for decision process measures in intertemporal choice task in Experiment 2

	Rotated Components			Communalities
	1	2	3	
AAD	.35	**.74**	-.27	.74
X-flip	.19	.02	**.88**	.80
Distance	**.89**	.17	.15	.85
Idle time	.02	**.76**	.47	.79
Motion time	**.91**	.13	.12	.85
Eigenvalues	2.23	.97	.84	
Variances accounted (%)	44.52	19.29	16.82	

Note. Loading greater than .6 was considered as significant.

Tables 16 and 17 respectively displayed the correlation matrix and PCA results in the gamble choice task. With eighty percent of explained variance as the cut-off value, the first three components explained 88.19% of variance in the gamble choice task. As shown in Table 17, Distance and Motion time were combined, Idle time was grouped with AAD, and X-flip made its own component. Following Experiment 1, these three components were labeled Locomotion, Conflict and Wavering, respectively.

Table 16

Correlations among decision process measures in gamble choice task in Experiment 2

	AAD	X-flip	Distance	Idle Time	Motion Time
AAD	----	.13	.54	.66	.43
X-flip		----	.28	.27	.17
Distance			----	.42	.69
Idle Time				----	.32

Table 17

Principal component analysis for decision process measures in gamble choice task in Experiment 2

	Rotated Components			Communalities
	1	2	3	
AAD	.35	**.85**	-.04	.84
X-flip	.12	.10	**.98**	.99
Distance	**.84**	.33	.17	.84
Idle time	.13	**.90**	.20	.87
Motion time	**.92**	.15	.04	.88
Eigenvalues	2.64	.92	.84	
Variances accounted (%)	52.87	18.47	16.85	

Note. Loading greater than .6 was considered as significant.

As in Experiment 1, component scores were obtained per person per context per selected option. Correlations were made between the mean components scores (collapsing across selected option) and self-reported experiences (four scales) in each context in each task. Similar to Experiment 1, Bonferroni α correction was adopted. With p = .004 as the cut-off value, in both tasks, none of the correlations was significant: the strongest correlation occurred between the mean Conflict component and self-report conflict rating in more-similar context in the intertemporal choice task, $r(44)$ = .38, p = .008.

In Experiment 2, Cronbach's α for the locomotion scale was .607 (n = 50). The average score across all participants was 3.96 out of 6. In neither task was there a significant relationship between the locomotion scale and the locomotion component (across less-similar and more-similar contexts): $r(44)$ = .038, p = .802 in the intertemporal choice task; $r(44)$ = -.090, p = .551 in the gamble choice task.

Testing H6 and H7: effect of similarity on decision process and decision process conditional on final choice. H6 and H7 expected to find that more conflict and uncertainty were detected in the more-similar context than in the less-similar context in both tasks. Furthermore, uncertainty (as represented by Wavering component) was predicted to be more sensitive than conflict in capturing the similarity effect. In addition, the study also expected to replicate the pattern that choosing the later larger gain over the sooner smaller one, and choosing the riskier larger gain over the safer smaller one resulted in greater conflict and uncertainty, as found in Experiment 1.

With PCA, component scores were obtained for each person in each context when choosing each type of the options. A 3 (components: Conflict, Wavering and Locomotion) * 2 (similarity: less-similar vs. more-similar) * 2 (selected option: sooner smaller gain vs. later larger gain in intertemporal choice; riskier larger gain vs. safer smaller gain in gamble choice) repeated-measures ANOVA was performed on the component scores in each task, with component, similarity and selected option as within-subjects factors. This ANOVA in each task, together with simple tests (if applicable), was used to test both H6 and H7, as shown below.

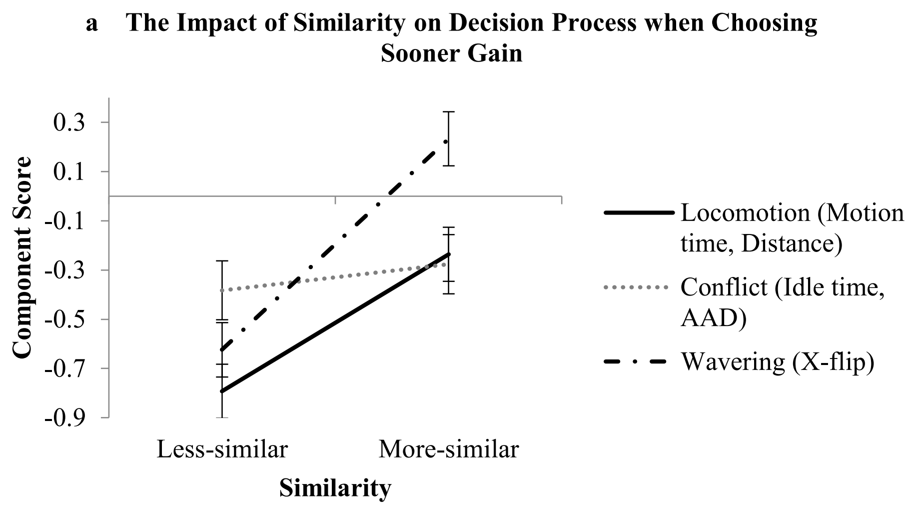
Effect of similarity. In the intertemporal choice task, the interaction between similarity, selected option, and component was significant, $F(2,44) = 4.72$, $p = .014$, partial $\eta 2 = .18$, *Wilks' Λ* = .82. The interaction between similarity and component was significant, $F(2,44) = 10.65$, $p < .001$, partial $\eta 2 = .33$, *Wilks' Λ* = .67. The interaction between selected option and component was significant, $F(2,44) = 4.56$, $p = .016$, partial $\eta 2 = .17$, *Wilks' Λ* = .83. The main effect of similarity was significant, $F(1,45) = 167.8$, p

< .001, partial $\eta 2$ = .79, *Wilks' Λ* = .21. The main effect of selected option was significant, $F(1,45) = 204.2$, $p < .001$, partial $\eta 2$ = .82, *Wilks' Λ* = .18. No other interactions or main effects were significant.

Simple tests were employed to unpack the triple interaction between similarity, choice and component in order to examine the components' ability to capture the similarity effect. Due to the triple interaction, the variation in components between the less-similar and more-similar contexts might be different when choosing different options. Hence, simple effects conditional one what was selected were explored to examine the difference in components between the less-similar and more-similar contexts.

When choosing the sooner option, the more-similar context led to a greater mean Wavering (mean Wavering in the more-similar context = .23, mean Wavering in the less-similar context = -.62), $F(1,45) = 20.27$, $p < .001$, partial $\eta 2$ = .31; but not greater mean Conflict (mean Conflict in the more-similar context = -.28, mean Conflict in the less-similar context = -.38), $F(1,45) = .38$, $p = .54$, partial $\eta 2$ = .008. Locomotion displayed a larger mean value in the more-similar context (mean Locomotion = -.24) than in the less-similar context (mean Locomotion = -.79), $F(1,45) = 13.93$, $p = .001$, partial $\eta 2$ = .24. There was no difference in the variation between Locomotion and Wavering (mean difference for Wavering = .86, mean difference for Locomotion = .56), $F(1,45) = 3.34$, $p = .074$, partial $\eta 2$ = .069.

When choosing the later larger option, the more similar-context led to a larger mean Wavering (mean Wavering in the more-similar context = .88; mean Wavering in the less-similar context = -.49), $F(1,45) = 61.10$, $p < .001$, partial $\eta 2 = .58$; and a larger mean Conflict (mean Conflict in the more-similar context = .61; mean Conflict in the less-similar context = .05), $F(1,45) = 6.26$, $p = .016$, partial $\eta 2 = .12$; but not a larger mean Locomotion (mean Locomotion in the more-similar context = .59; mean Locomotion in the less-similar context = .43), $F(1,45) = .85$, $p = .363$, partial $\eta 2 = .02$. Furthermore, Wavering showed a larger variation than did Conflict to capture the similarity effect (mean Wavering difference = 1.37, mean Conflict difference = .55), $F(1,45) = 5.98$, $p = .018$, partial $\eta 2 = .12$. Figure 6(a-b) depicts the components' variation when responding to different levels of similarity. As shown in the figure, Wavering displayed the largest variation between the less-similar and more-similar contexts; the Conflict component was affected by similarity only when selections were towards the larger, delayed gain.



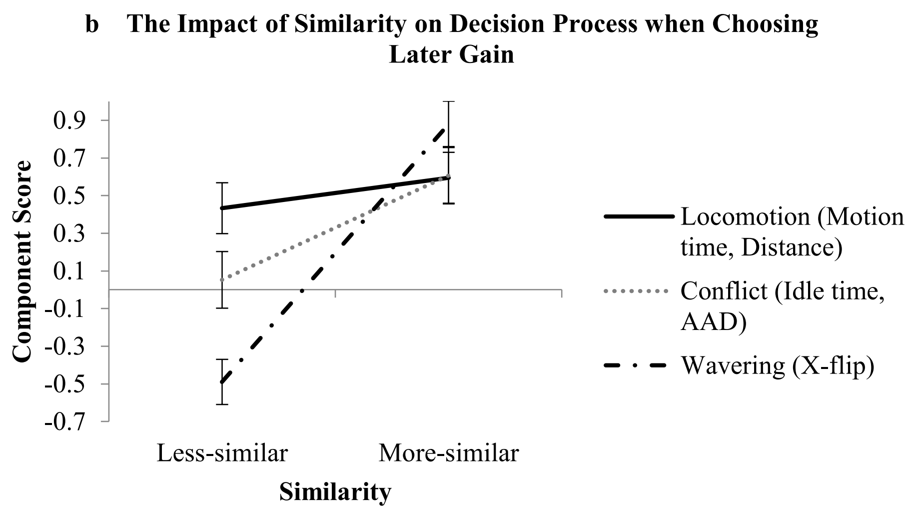


Figure 6(a-b). The impact of similarity on decision process when choosing the sooner gain and later gain, respectively.

In the gamble choice task, the main effect of similarity was significant, $F(1,45) = 170.8$, $p < .001$, partial $\eta 2 = .79$, *Wilks' Λ* = .21, (means for Wavering, Conflict and Locomotion in the more-similar context were .49, .22, and .34, respectively; means for

Wavering, Conflict and Locomotion in the less-similar context were -.49, -.22, and -.34, respectively). The main effect of choice was significant, $F(1,45) = 68.1$, $p < .001$, partial $\eta 2 = .60$, *Wilks' Λ* = .40 (means for Conflict, Wavering and Locomotion when choosing the riskier option were .24, .15, and .34, respectively; means for Conflict, Wavering and Locomotion when choosing the safer option were -.24, -.15, and -.34, respectively. More details regarding the process conditioned on selected option please refer to the next section). No other interactions or main effects reached a $p = .05$ level.

Following Hypothesis 7, a pre-planned test showed that Wavering had a larger difference between the more-similar and less-similar contexts (mean Wavering difference = .98) than did Conflict (mean Conflict difference = .44), $F(1,45) = 5.10$, $p = .029$, partial $\eta 2 = .10$. By contrast, there was no difference in such a variation between Conflict and Locomotion, or between Locomotion (mean Locomotion difference = .68) and Wavering. Figure 7 illustrates the components' variation between the less-similar and more-similar conditions in the gamble choice task. As can be seen in the figure, Wavering was more sensitive than was Conflict to index the contextual similarity effect.

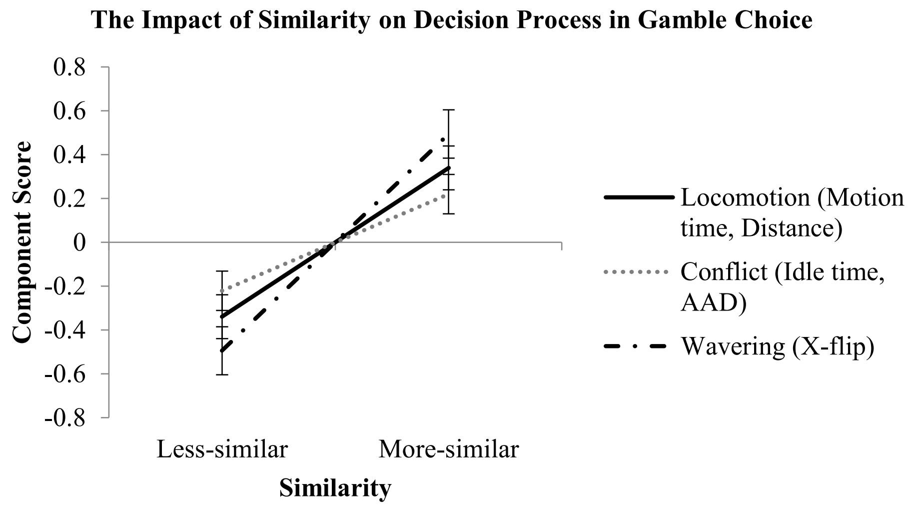


Figure 7. The impact of similarity on decision process in gamble choice.

Process conditional on final choice. H7 proposed that choosing different options was associated with different process variation. As reported, in the intertemporal choice task, there was a triple interaction between component, choice and similarity. Hence, simple tests were adopted to unpack the interaction to test the relationship between what was selected and component. Given the triple interaction, the relationship between what was selected and component might vary depending on the level of similarity. Thus, simple effect tests conditional on similarity were adopted to examine the relationship between component and what was selected.

In the less-similar context, choosing the later larger gain led to a greater mean Conflict (mean Conflict when choosing the later gain = .05; mean Conflict when choosing the sooner gain = -.38), $F(1,45) = 5.0$, $p = .030$, partial $\eta 2 = .10$; but not to a greater mean Wavering (mean Wavering when choosing the later gain = -.49; mean

Wavering when choosing the sooner gain = -.62), $F(1, 45) = .58$, $p = .450$, partial $\eta 2$ = .01. Locomotion also displayed a larger mean when choosing the later larger gain over the sooner smaller one (mean Locomotion when choosing the later gain = .43; mean Locomotion when choosing the sooner gain = -.79), $F(1,45) = 48.08$, $p < .001$, partial $\eta 2$ = .52. Moreover, Locomotion showed a larger variation than did Conflict (mean difference for Locomotion = 1.22; mean difference for Conflict = .43), $F(1,45)= 11.42$, $p = .001$, partial $\eta 2 = .20$.

In the more-similar context, choosing the later larger gain resulted in a larger mean Conflict (mean Conflict when choosing the later gain = .61; mean Conflict when choosing the sooner gain = -.28), $F(1,45) = 29.20$, $p < .001$, partial $\eta 2 = .39$; a larger mean Wavering (mean Wavering when choosing the later gain = .88; mean Wavering when choosing the sooner gain = .23), $F(1,45) = 13.52$, $p = .001$, partial $\eta 2 = .23$; and a larger mean Locomotion (mean Locomotion when choosing the later gain = .59; mean Locomotion when choosing the sooner gain = -.24), $F(1,45) = 20.83$, $p < .001$, partial $\eta 2$=.32. Additionally, there was no difference in the variation between any of the two components when choosing the later larger option over the sooner one, F-values $\leq .85$, p-values $\geq .362$.

In the gamble choice task, because the main effect of selected option was significant ($F(1,45) = 68.1$, $p < .001$, partial $\eta 2 = .60$, $Wilks' \Lambda = .40$) and there was no interaction between choice and any other factor, the results indicated that choosing the riskier larger gain over the safer smaller one led to greater Conflict, Wavering and Locomotion (means for Conflict, Wavering and Locomotion when choosing the riskier option were .24, .15, and .34, respectively; means for Conflict, Wavering and Locomotion when choosing the safer option were -.24, -.15, and -.34, respectively). Moreover, these components' variation between when choosing the riskier option and when choosing the safer option were at the same level.

Taken together, both tasks showed that Wavering captured the similarity effect to a greater extent than did Conflict. In other words, uncertainty was the major source for decision difficulty in a context where options were similar to each other. Additionally, similar to Experiment 1, selecting the later larger gain over the sooner smaller one in the intertemporal choice task (except in the less-similar context), and selecting the riskier larger gain over the safer smaller one in the gamble choice task led to more conflict and uncertainty. This implies that going against the base tendency of selecting the short-sided reward, or going against selecting the safer option results in both conflict and uncertainty.

The variation of the components was consistent with that observed with individual measures. For example, more directional flips were found in the more-similar context than in the less-similar context in both tasks. Descriptive statistics off all dynamic measures can be found in Appendix D.

Testing H8: role of numeracy in decision process. H8 predicted that when choosing the dominant option, the process was not affected by numeracy because the decision was easy to make. However, when the dominant option was not available, numeracy was predicted to be negatively related to Idle time and to the Conflict component.

In Experiment 2, the average correct rate of numeracy was 43.8% (n = 50). The Cronbach alpha was .619. In each task, correlations were made between numeracy and each of the five individual measures (obtained by collapsing all conditions) for the experimental choice pairs (i.e., no dominant option was available). With $p = .01$ as the cut-off value, across all participants, there was no significant relationship between numeracy and mean Idle time (natural-log transformed, collapsed by context and what was selected), $r(44) = -.14$, $p = .354$. As for components, with $p = .017$ as the cut-off value, numeracy was negatively related to the mean Conflict component (collapsed by context and what was selected), $r(44) = -.38$, $p = .009$. No other significant relationship was found between numeracy and any individual measure (regardless of whether a dominant option was available) or component when the dominant option was available, all *p*-values > .05.

In the gamble choice task, with $p = .01$ as the cut-off value, when participants had to make trade-offs, numeracy was negatively related to mean Motion time, $r(44) = -.42$, $p = .004$, and mean AAD, $r(44) = -.50$, $p < .001$. In addition, numeracy was negatively related to mean Conflict, $r(44) = -.41$, $p = .004$, with $p = .017$ as the cut-off value. No other correlation between numeracy and individual measure (regardless of whether a dominant option was available) or component reached a statistical significance level in the gamble choice task, all *p*-values > .05.

Experiment 2 Discussion

Experiment 2 replicated Experiment 1 in several aspects. First, the three-component structure was replicated in both intertemporal choice and gamble choice tasks.

Second, Experiment 2 also replicated the pattern that participants experienced a higher level of conflict and uncertainty when choosing the later larger gain over the sooner smaller one the intertemporal choice task, and when choosing the riskier larger gain over the safer smaller one in the gamble choice task. Third, numeracy was negatively related to the Conflict component in both tasks, indicating that participants with poorer numerical ability had greater conflict experience when making decisions.

The primary purpose of Experiment 2 was testing the impact of similarity on action dynamics. In particular, it was of interest to compare the ability to capture the similarity effect between the Conflict and Wavering components. It was found that in both tasks, the variation between the less-similar and more-similar contexts was more pronounced in the Wavering component than in the Conflict component. Thus, consistent with the hypothesis, participants experienced more uncertainty than conflict in the context where options were more similar, and uncertainty was the major source of decision difficulty in such a context.

Experiment 3

Experiment 3 adopted a consumer choice task. There are three purposes of this experiment. First, the experiment aimed to replicate the structure of components in the previous two experiments in a new decision domain. Second, Experiment 3 also manipulated the similarity between the options and it was expected that participants would exhibit greater uncertainty in the more-similar condition. Third, the experiment manipulated the importance of the task, aiming to test the variation of conflict and uncertainty when the choice is more or less important.

The consumer choice task in Experiment 3 asked participants to make trade-offs between hotel quality (as described by previous consumers' rating) and price. In this experiment, the manipulations of similarity and importance are both within-subjects factors. The similarity manipulation is like that of Experiment 2. That is, in the more-similar situation, attributes appeared more similar between the two options. For the importance manipulation, participants read instructions intended to affect the importance of the decision. In the less-important condition, participants were told that due to the severe weather, they had to find a hotel to stay temporally. In the more-important condition, the purpose of choosing a hotel was to celebrate the participant's graduation. Participants were informed that their family members were coming to the hotel for the celebration, heightening the importance of making sure the venue was enjoyed by all. More details of the instructions are found below. Similar to the previous experiments, dominant options were added as a manipulation check.

Hypotheses in Experiment 3

Structure of action dynamics (H9). As done in Experiments 1 and 2, it is hypothesized that the action dynamic measures will be differentiated into the Conflict component, represented by Idle time and AAD, the uncertainty component (Wavering), represented by X-flip, and the Locomotion component, consist of Motion time and Distance.

The effect of similarity (H10). It is hypothesized that the uncertainty component is expected to show the greatest variation between the two contexts when compared to the other components.

The effect of importance (H11). For the experimental choice pairs, it is hypothesized that conflict and uncertainty are greater when choosing the more expensive hotel in the less-important condition. By contrast, the feeling of conflict and uncertainty is predicted to be less significant when choosing the more expensive hotel than when choosing the cheaper hotel in the more-important condition. This is because graduation celebration provides a good reason to select a better hotel, thus there is less conflict when selecting a more expensive option for a good reason.

Numeracy and action dynamics (H12). When facing non-dominant options, it is hypothesized that high numerate people are likely to show shorter Idle time in the consumer choice task. In addition, it is expected that lower numerate people will exhibit more conflict in this task. When facing the dominant options, numeracy is not expected to play a significant role when making choices, regardless of the condition, because decisions are easy to make.

Experiment 3 Methods

Participants. Fifty-three college students (thirty females) participated in the study for course credit.

Materials stimuli. The materials and stimuli were similar to previous two experiments.

Trajectory tracking program. This is the same program used in the other two experiments.

Choice pairs. In the consumer choice task, there were two types of choice pairs. For each participant, there were 15 pairs in which a dominant option was available. Additionally, there were also 40 experimental choice pairs in which choices were made between a more expensive hotel with higher quality rating, and a cheaper one with lower quality rating. Participants were informed that the quality rating in this experiment was similar to the rating system in Booking.com. In this experiment, the quality rating ranged from 0 -100, and took cleanliness, comfort, location, facilities, staff, and free WiFi into account. As an example, one decision was made between Hotel A: the rating of the hotel is 72 and the price of this hotel is $99 per night, and Hotel B: the rating of the hotel is 40 and the price of this hotel is $45 per night. On average, the price and rating for the higher-rated hotel were $114 and 69, respectively. The average price and rating for the lower-rated hotel were $71 and 44, respectively. Choice pairs were presented with a sequence shown in Table B3 in Appendix B.

Similarity was manipulated in the same manner as done in Experiment 2: the attribute differences in the more-similar condition was closer than those in the less-similar condition.

The following paragraphs were used for the manipulation of importance:

Less-important condition instructions: After visiting Columbus, you had planned to drive back to Athens tonight, but a storm is coming and for safety reasons you decide to stay in Columbus instead. The following hotels are presented with price per night, and customers' evaluation. The evaluation takes cleanliness, comfort, location, facilities, staff, and free WiFi into account. The best score is 100. Please select a hotel based on your preference.

More-important condition instructions: After years of hard work, you are finally graduating, and your entire family is coming to watch. Your parents are letting you choose a hotel where you want to celebrate this special occasion. You want to make the celebration an unforgettable event. The following hotels are presented with price per night, and customers' evaluation. The evaluation takes cleanliness, comfort, location, facilities, staff, and free WiFi into account. The best score is 100. Please select the hotel based your preference.

Scales and self-reported measures. Numeracy scale, locomotion scale and self-reported experiences (i.e., difficulty, conflict, confidence and satifactory) used in Experiments 1 and 2 were also adopted in the third experiment.

Procedures. Each participants completed the experiment individually in a cubicle. Participants completed the numeracy and locomotion scales before engaging in the choice task. In the choice task, the manipulation of similarity and importance were both within-subjects factors. The presentation sequence of the conditions were counterbalanced across participants. After completing choices in each condition, participants completed the self-reported decision experiences scales. Then they took a break. After completing all four conditions in the consumer choice task, the experiment was finished and participants were debriefed.

Data analysis. Similar to previous two experiments, averages were taken for each measure based on the contextual manipulation and which option was chosen. As a result, in the consumer choice task, each participant gave 12 values for each measure: 2 (less-similar vs. more-similar) * 2(less-important vs. more-important) * 3 (three different option types). Idle time and Motion time were transformed with natural-log. Two participants were excluded from the analyses because they had values that were beyond three standard deviations above the mean in each measure. Hence, the sample size was 51 in Experiment 3.

Experiment 3 Results

Choice preference and manipulation check. For satisfying the dominance effect, in each of the more-similar/more-important and less-similar/more-important context, one participant failed to select the dominant option when it was available. In each of the more-similar/less-important and less-similar/less-important context, two participants each failed to select the dominant option when it was available. In other words, across 3060 trials in which the dominant option was available, participants did not select this option five times (i.e., satisfying dominance in 99.9% trials). In addition, the mean values of all measures were always the smallest when choosing the dominant option. Moreover, the process in which the dominant option was selected was not affected by either similarity or importance. Table 18 displays the mean frequencies of choosing different options in different conditions. Table 19 shows the means of each measure in different contexts when choosing different options. More detailed results about dominance found be found Appendix E.

To test the impact of similarity and importance on choice preference, a 2 (similarity: less-similar vs. more-similar)* 2 (importance: less-important vs. more important) * 2 (choice selection: cheap vs. expensive) repeated-measures ANOVA was performed on the frequencies of choosing different options, with similarity, importance and selected option as within-subjects factors.

Table 18

Mean frequencies of choosing different options as a function of similarity and importance in Experiment 3

Option	More-similar, more-important	More-similar, less-important	Less-similar, more-important	Less-similar, less-important
Cheap	17.27 (.57)	21.78 (.43)	16.90 (.55)	21.37 (.37)
Expensive	22.73 (.57)	18.22 (.43)	23.10 (.55)	18.63 (.37)
Dominant	14.98 (.02)	14.96 (.03)	14.98 (.02)	14.96 (.03)

Note. Numbers in parentheses are standard errors. For cheap and expensive options, they are out of 40 trials per person. For the dominant option, it is out of 15 trials per person.

The interaction between importance and choice was significant, $F(1,50) = 58.94$, $p < .001$, partial $\eta 2 = .54$. The main effect of choice was significant, $F(1,50) = 5.97$, $p = .018$, partial $\eta 2 = .11$. No other interaction or main effect was significant. Simple tests were used to provide more detailed results. It was found that participants chose the more expensive hotel more frequently in the more-important context (mean frequency = 22.91 out of 40, 57.3%) than in the less-important context (mean frequency = 18.42 out of 40, 46.1%), $F(1,50) = 58.94$, $p < .001$, partial $\eta 2 = .54$.

Table 19

Means of action dynamic measures when choosing different options (including the dominant option) in each testing condition in Experiment 3

Pair		Idle	Motion	Distance	X-flip	AAD
Exp	More-similar					
	More-important					
	Cheap	4.84 (.11)	1.85 (.05)	30.91 (.53)	3.0 (.06)	4.70 (.15)
	Expensive	5.78 (.10)	2.22 (.04)	37.12 (.67)	3.62 (.08)	5.79 (.18)
	Less-important					
	Cheap	4.79 (.08)	1.95 (.04)	32.26 (.54)	3.17 (.10)	4.52 (.12)
	Expensive	5.75 (.11)	2.29 (.06)	37.07 (.77)	3.75 (.13)	5.70 (.16)
	Less-similar					
	Less-important					
	Cheap	4.76 (.10)	1.81 (.04)	30.45 (.49)	2.89 (.10)	4.61 (.12)
	Expensive	5.55 (.11)	2.22 (.05)	36.01 (.58)	3.15 (.09)	5.54 (.18)
	Less-important					
	Cheap	4.55 (.09)	1.93 (.05)	31.23 (.62)	2.98 (.11)	4.39 (.14)
	Expensive	5.65 (.11)	2.23 (.05)	34.94 (.66)	3.12 (.12)	5.69 (.16)
Domi	More-similar					
	More-important	2.09 (.01)	.97 (.005)	19.04 (.06)	.072 (.008)	.91 (.007)
	Less-important	2.05 (.03)	.99 (.02)	19.24 (.05)	.058 (.01)	.93 (.01)
	Less-similar					
	More-important	2.11 (.02)	1.01 (.04)	18.96 (.09)	.064 (.009)	.96 (.03)
	Less-important	2.08 (.03)	.96 (.01)	19.16 (.05)	.060 (.008)	.92 (.008)

Note. Numbers in parentheses are standard errors. Units for Idle time and Motion time were seconds. Units for Distance and AAD were centimeters. The values for Idle and Motion times in this table were not natural-log transformed. For pair, Exp = experiment choice pair; Domi = dominant choice pair.

A 2 (similarity: less-similar vs. more-similar) * 2 (importance, less-important vs. more-important) repeated-measures ANOVA was performed on each self-report measure, with similarity and importance as within-subjects factors. Because there were four self-report measures and repeated-measures ANOVA was run four times accordingly, Bonferroni α correction was adopted, with $p = .013$ as the cut-off value. Table 20 shows the means of self-report measures in Experiment 3. Participants felt greater difficulty in the more-similar condition than in the less-similar condition, $F(1,50) = 17.42$, $p < .001$, partial $\eta 2 = .26$, $Wilks' \Lambda = .74$; and in the more-important condition than in the less-important condition, $F(1,50) = 82.79$, $p < .001$, partial $\eta 2 = .62$, $Wilks' \Lambda = .38$. Participants also felt more conflict in the more-similar condition than in the less-similar condition, $F(1,50) = 32.67$, $p < .001$, partial $\eta 2 = .39$, $Wilks' \Lambda = .61$; and in the more-important condition than in the less-important condition, $F(1,50) = 40.12$, $p < .001$, partial $\eta 2 = .45$, $Wilks' \Lambda = .56$. Participants felt less confident in the more-important condition than in the less-important condition, $F(1,50) = 41.73$, $p < .001$, partial $\eta 2 = .46$, $Wilks' \Lambda = .55$. However, the effect of similarity on confidence was not significant, $F(1,50) = 5.36$, $p = .025$, partial $\eta 2 = .10$, $Wilks' \Lambda = .90$. Participants were more satisfied with their decisions in the less-important condition than in the more-important condition, $F(1,50) = 14.41$, $p < .001$, partial $\eta 2 = .22$, $Wilks' \Lambda = .78$. By contrast, satisfaction was not affected by similarity, $F(1,50) = .67$, $p = .418$, partial $\eta 2 = .01$, $Wilks' \Lambda = .99$. No interaction was found between importance and similarity in any test.

Table 20

Self-reported experiences in each context in Experiment 3

		Difficulty	Conflict	Confidence	Satisfactory
More-similar					
	More-important	6.43 (.17)	6.45 (.17)	4.86 (.18)	5.28 (.23)
	Less-important	4.45 (.19)	4.84 (.23)	5.88 (.16)	6.20 (.19)
Less-similar	More-important	6.08 (.17)	5.18 (.19)	5.18 (.21)	5.33 (.17)
	Less-important	3.71 (.20)	4.06 (.18)	6.43 (.19)	5.86 (.17)

Note. Numbers in parentheses are standard errors.

Testing H9: structure of action dynamic measures. H9 predicted that the three-component structure would be replicated in the consumer choice task. Table 21 displays the correlation matrix among action dynamic measures in this task. X-flip was not related to any other measure. AAD appeared to be associated with Distance, Idle time and Motion time. However, its relationship with Idle time was the strongest. The relationship between Distance and Motion time was high, as also found in other experiments. Table 22 shows the results of PCA. Consistent with the other two experiments, the first three components were able to explain 86.09% of variance. Again, Idle time was grouped with AAD, Distance was grouped with Motion time, and X-flip made an independent component.

Table 21

Correlations among action dynamic measures in Experiment 3

	AAD	X-flip	Distance	Idle Time	Motion Time
AAD	----	.06	.46	.63	.32
X-flip		----	.13	.10	.05
Distance			----	.45	.64
Idle Time				----	.32

Table 22

Principal component analysis for decision process measures in consumer choice task

	Rotated Components			Communalities
	1	2	3	
AAD	**.88**	.21	.01	.82
X-flip	.04	.04	**.99**	.99
Distance	.36	**.82**	.09	.80
Idle time	**.88**	.20	.06	.82
Motion time	.12	**.93**	-.01	.87
Eigenvalues	2.44	.98	.88	
Variances accounted (%)	48.76	19.68	17.65	

Note. Loading greater than .6 was considered as significant.

Component scores were derived per person in each context when selecting each type of the options. Table 23 displays the relationships between components and the self-reported decision experiences (after collapsing across the chosen options) in each context. As the other two experiments, $p = .004$ were as the cut-off value. In the more-similar/more-important context, self-reported confidence was negatively related to the mean Wavering component across all participants, $r(49) = -.40$, $p = .004$. In the less-similar/more-important context, self-reported confidence was also negatively related to the mean Wavering component, $r(49) = -.40$, $p = .003$. No other relationship reached the statistical significance in any context. Thus, self-reported uncertainty (confidence) and the Wavering component appeared to capture a similar decision difficulty state in some situations.

In Experiment 3, the Cronbach's α for the locomotion scale was .614 (n = 53). The average score was 3.97 out of 6. There was no significant relationship between the locomotion scale and the locomotion component, $r(49) = -.03$, $p = .864$.

Table 23

Self-reported decision experience in different contexts in Experiment 3

			Difficulty	Conflict	Confidence	Satisfaction
More-similar						
	More-important	Conflict	-.08	.25	.17	.01
		Wavering	.09	.06	-.40*	-.01
		Locomotion	.13	-.28	.05	.17
	Less-important	Conflict	-.03	.14	-.12	-.13
		Wavering	-.06	-.12	-.38	.18
		Locomotion	-.03	.21	.21	.10
Less-similar	More-important	Conflict	.03	.18	.30	-.20
		Wavering	.12	-.04	-.40*	.04
		Locomotion	-.08	-.13	.004	.17
	Less-important	Conflict	-.13	-.03	-.12	.08
		Wavering	.29	.08	-.01	.07
		Locomotion	-.09	-.08	-.01	.13

Note. *: $p \leq .004$. The p-values in Table 23 were subject to Bonferroni α correction, with $p = .004$ (12 correlations per context per task) as the cut-off value.

Testing H10 and H11: effects of similarity, importance, and decision processes conditional on selected option. H10 and H11 examined the impacts of similarity and importance on decision process, and the relationship between what was selected and decision process. For each component, scores were obtained for each person in each context when choosing each type of the options. A 2 (similarity, less-similar vs. more-similar)* 2(importance: less-important vs. more important) * 2 (selected option, cheap vs. expensive) * 3 (component: Conflict vs. Locomotion vs. Wavering) repeated-measures ANOVA was performed on component scores, with similarity, importance, selected option and component as within-subjects factors. The triple interaction between similarity, choice, and component was significant, $F(2,49) = 8.98$, $p < .001$, partial $\eta 2 = .27$, *Wilks' Λ* = .73; the double interaction between similarity and choice was significant, $F(1,50) = 7.01$, $p = .011$, partial $\eta 2 = .12$, *Wilks' Λ* = .88; the double interaction between choice and component was significant, $F(2,49) = 17.32$, $p < .001$, partial $\eta 2 = .41$, *Wilks' Λ* = .59; the main effect of choice was significant, $F(1,50) = 326.3$, $p < .001$, partial $\eta 2 = .87$, *Wilks' Λ* = .13; and the main effect of similarity was significant, $F(1,50) = 33.90$, $p < .001$, partial $\eta 2 = .40$, *Wilks' Λ* = .60. No other interactions or mains effects were significant. Thus, the results indicated that decision process was not affected by importance, although importance had an impact on choice preference. Analyses of individual measures also showed that importance did not have a significant impact on those measures (Appendix E). The effect of similarity and the relationship between choice and component were tested below.

Effect of similarity. The purpose of this section was to test whether components varied in the expected direction between the more-similar and less-similar contexts. The triple interaction between similarity, choice and component implied that the effect of similarity on component varied as a function of what was selected. Thus, to test the effect similarity on component more precisely, simple effect tests conditional on the selected option were employed to analyze the variation in component scores between the more-similar and less-similar contexts.

First, conditional on choosing the cheaper hotel, mean Conflict did not vary between the more-similar (mean = -.40) and less-similar (mean = -.53) contexts when collapsing across importance, $F(1,50) = 1.46$, $p = .232$, partial $\eta 2$ =.03. Wavering showed a larger mean value in the more-similar context (mean = -.13) than in the less-similar context (mean = -.32), $F(1,50) = 3.24$, p =.078, partial $\eta 2$ =.06, although it did not reach statistical significance. Locomotion did not show a significant variation between the contexts (means equal to -.37 and -.45 in the more- and less-similar contexts, respectively), $F(1,50) = .35$, $p = .558$, partial $\eta 2$ = .007.

Second, conditional on choosing the more expensive hotel, mean Conflict did not very between the more-similar (mean = .53) and less-similar (mean = .41) contexts, $F(1,50) = .98$, $p = .328$, partial $\eta 2$ = .02. Wavering showed a significantly lager mean value in the more-similar context (mean = .59) than in the less-similar context (mean = -.14), $F(1,50) = 29.44$, $p < .001$, partial $\eta 2$ = .37. Locomotion did not show a significant variation between the contexts (means equal to .49 and .33 in the more- and less-similar contexts, respectively), $F(1,50) = 1.60$, $p = .211$, partial $\eta 2$ = .03.

Figure 8(a-b) shows the impact of similarity on decision process. Consistent with Experiment 2, Wavering was the most sensitive component when responding to the similarity effect, regardless of which option was chosen. Given the trends of the components when comparing the less- and more-similar conditions in the two selected options in Figure 8, and the observed main effect of similarity, we proceeded to compare the means of the components in the more-similar and less-similar conditions when collapsing across selected option and importance. Only the Wavering component resulted in a significantly greater mean value in the more-similar condition (mean = .23) than in the less-similar condition (mean = -.23), $F(1,50) = 17.22$, $p < .001$, partial $\eta 2 = .26$.

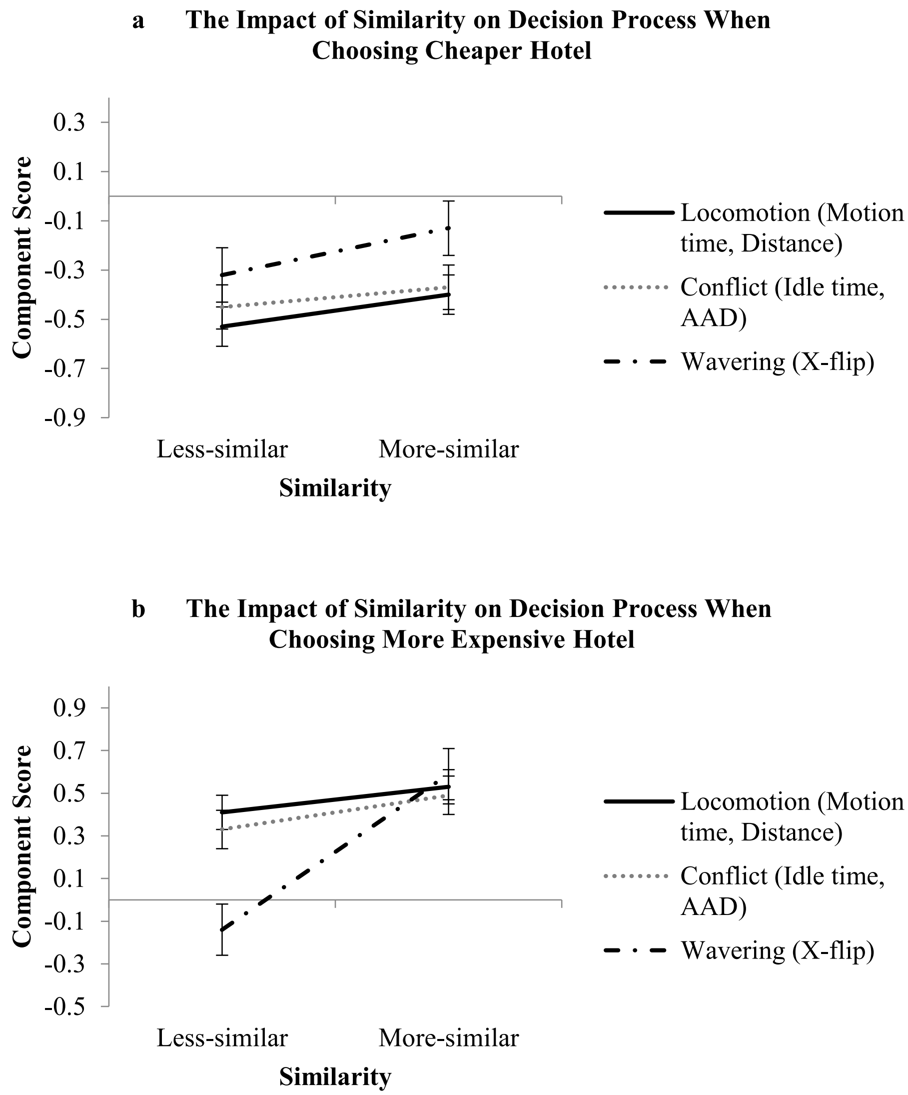


Figure 8(a-b). The impact of similarity on decision process when choosing the cheaper and more expensive hotels.

Process conditional on final choice. The purpose of this section was to examine whether the variation in components was associated with what was selected. Given the triple interaction between similarity, choice and component, the relationship between component and what was selected varied as a function of similarity. Hence, simple effect tests conditional on similarity were adopted to examine the relationship between what was selected and component.

In the more-similar context, choosing the more expensive hotel led to greater Conflict than when selecting the cheaper hotel (means were .53 and -.40 when choosing the more and less expensive hotel, respectively). For Wavering, the means were .59 and -.13 when choosing the more expensive and the cheaper hotels, respectively; and for Locomotion the corresponding means were .49 and -.37 for more and less expensive hotels, respectively). All of the mean differences were significant as given by: $F(1,50) = 59.08$, $p < .001$, partial $\eta2 = .54$ for Conflict; $F(1,50) = 99.18$, $p < .001$, partial $\eta2 = .67$, for Wavering, and $F(1,50) = 43.83$, $p < .001$, partial $\eta2 = .47$ for Locomotion. Comparing the mean changes among components, none were significantly different.

In the less-similar context, choosing the more expensive hotel led to significantly greater Conflict (means were .46 and -.53 when choosing the more expensive and cheaper hotels respectively), Wavering (means were -.14 and -.32 when choosing the more expensive and cheaper hotels respectively), and Locomotion (means were .33 and -.45 when choosing the more expensive and cheaper hotels respectively): $F(1,50) = 78.66$, $p < .001$, partial $\eta2 = .61$, for Conflict; $F(1,50) = 8.34$, $p = .006$, partial $\eta2 = .14$, for Wavering; and $F(1,50) = 41.15$, $p < .001$, partial $\eta2 = .45$ for Locomotion. Furthermore, Conflict displayed a larger variation than did Wavering (mean Conflict variation = .99; mean Wavering variation = .18), $F(1,50) = 38.42$, $p < .001$, partial $\eta2 = .44$. Locomotion also showed a larger variation than did Wavering (mean Locomotion variation = .78), $F(1,50) = 20.53$, $p < .001$, partial $\eta 2 = .29$. There was no difference in the variation between Conflict and Locomotion, $F(1,50) = .86$, $p = .358$, partial $\eta 2 =.02$.

Taken together, it was found that similarity was associated with greater uncertainty (Wavering). In terms of what was selected, choosing the more expensive hotel over the cheaper one led to more conflict and uncertainty, regardless of importance and similarity.

Tests of individual measures are found in Appendix E. In general, participants exhibited more directional flips in the more-similar than in the less-similar context. They also showed longer response times and more deviant trajectories when choosing the more expensive hotel over the cheaper hotel in agreement with the results based on PC components.

Testing H12: role of numeracy in decision process. H12 predicted that numeracy to be negatively related to Idle time and the Conflict component. On average, the correct response rate was 51.2%. The Cronbach's α was low and equal to .260. When the dominant option was not available, numeracy was negatively related to mean Idle time (natural-log transformed, collapsed across all contexts and what was selected. Same for other measures and components), $r(49) = -.55$, $p < .001$, with $p = .01$ as the cut-off value. Consistently, numeracy was negatively related to the Conflict component, $r(49) = -.45$, $p = .001$, with $p = .017$ as the cut-off value. When the dominant option was available, numeracy was not related to Idle time, $r(49) = -.19$, $p = .186$. No other correlations between numeracy and any measure or component reached a statistical significance level.

Correlation between numeracy and decision process across three experiments. For each person in each experiment, a general score was computed for each component by collapsing all conditions (selected option, manipulation of the context, and task). In a similar vein, a general measure value (excluding data when choosing the dominant option) was computed by collapsing all condition in each experiment for each person. Across all participants in the three experiments (n = 143), the average correct rate was 47.9%, and Cronbach's α was .530. Correlations were made between numeracy and components and individual measures. It was found that numeracy was significantly related to the mean Conflict component, $r(141) = -.51$, $p < .001$, with $p = .017$ as the cut-off value, indicating that people with a better numerical ability tended to show less conflict. Additionally, mean Idle time appeared to be associated with numeracy, $r(141) = -.21$, $p = .012$, with $p = .01$ as the cut-off value. No other correlations reached a significance level, all p-values > .05.

Experiment 3 Discussion

Experiment 3 further replicated the three-component structure in a consumer choice task where similarity and importance were manipulated, indicating that conflict and uncertainty were common sources for decision difficulty in different decision domains. In addition, it was found that participants displayed greater conflict and uncertainty when choosing the more expensive hotel over the cheaper hotel in all testing conditions. The pattern resembled the finding in Luce et al (1999) where participants reported that they felt greater difficulty when choosing the more expensive cars although these cars had better safety features. Alternatively, the pattern might be due to the characteristics of the sample: college students usually cannot easily afford expensive hotels; hence, when they chose the more-expensive one, they experience greater conflict and uncertainty.

Experiment 3 also replicated the similarity effect found in Experiment 2: the components of Conflict and Wavering had a higher value in the more-similar context. When comparing conflict and uncertainty in terms of the similarity effect, uncertainty was more evident in its response to the manipulation of similarity. Furthermore, as in the previous two experiments, numeracy was negatively associated with the conflict component, indicating that lower numerate people had greater conflict when making decisions. This pattern was also replicated by computing the correlation between numeracy and the Conflict component across all participants in the three experiments.

In Experiment 3, although the manipulation of task importance had a significant impact on choice preference, it did not affect decision process, regardless of at the component level or at the individual measure level. In other words, despite that participants showed a stronger preference toward the more-expensive hotel in the more-important condition, their experience of conflict and uncertainty remained constant. The results imply that providing persuasive reasons might be able to motivate people to make more appropriate decisions based on the particular context. However, the reasons could not reduce the difficulty feeling when making decisions. On the other hand, in both Experiments 2 and 3, the manipulation of similarity had no impact on choice preference, however, it did affect decision process. The findings emphasized the importance of studying decision process directly, because decision preference is not necessarily informative about decision process.

General Discussion

The primary purpose of the present study was to unpack decision difficulty, and examine the situational and individual characteristics that were closely associated with decision difficulty. In the current work, decision difficulty was manipulated via the sign of the context, the similarity of the options, and the importance of the task. With retrospective self-report ratings of experienced difficulty, conflict and confidence, it was found that it was more difficult to make choices in the loss context in the gain context, when the options were more similar than less similar, and when the task was more important than less important.

Beyond the traditional self-report measures, the present study employed action dynamics, which is based on cursor movement and process-tracing, to investigate the research goal. Across three studies and different decision domains (i.e., intertemporal choice, gamble choice and consumer choice), a common finding was that the five action dynamic measures could be grouped into three distinct components, and these components varied differently when decision difficulty was manipulated via different ways. Thus, decision difficulty was able to be unpacked into different sources.

In Experiment 1, the sign of the decision context was manipulated, and it was found that conflict, rather than uncertainty was the major source of decision difficulty. In other words, in the loss domain, it was the trade-off between losing money and time/probability that led to decision difficulty. By contrast, in Experiments 2 and 3, the similarity of the options were manipulated. Participants displayed greater directional flips when the options were more similar to each other. Moreover, the variation of the

Wavering component was larger than that of the Conflict component. Thus, when options were harder to discriminate, the major source of experienced decision difficulty was uncertainty. The findings above demonstrated that decision difficulty was a multi-dimensional construct, and could be unpacked into distinct facets, such as conflict and uncertainty. However, it is also worth mentioning that conflict and uncertainty, albeit distinct, can coexist. As an example, in Experiment 3, when participants chose the more expensive hotel, they experienced more conflict and uncertainty, regardless of the similarity of the context.

The study also advanced the validity of action dynamic measures and the methodology of process tracing. Previous studies with action dynamics were able to show which context was more difficult by displaying longer response times and/or more deviant trajectories (Koop & Johnson, 2011; Dshemuchadse et al, 2013; Koop, 2013; Koop & Johnson, 2013). However, they did not specify the exact source of decision difficulty and related context. The present study illustrated that different action dynamic measures could be grouped together. More importantly, the derived components were able to vary in the expected direction when the contextual setting was changed. Thus, the study showed that the information based on trajectory was not only able to index the global feeling, but also able to differentiate more specific and subtle psychological states in the decision process.

Throughout three experiments, there was no consistent relationship between derived components and self-report measures. The findings implied that action dynamics and self-report measures captured different aspects of decision difficulty. That is, whereas action dynamics represented online measures of ongoing cognitive processes, self-report measures were best at describing global experiences in a retrospective manner. The distinction between action dynamics and self-report measures highlights the meaning of using process-tracing because it provides a useful tool to investigate online processes. In addition, one advantage of action dynamics over the retrospective self-report is that the latter methodology may lose validity due to memory error or recall bias (Dagnall, Munley, & Parker, 2008; Solhan, Trull, Jahng & Wood, 2009). By contrast, action dynamics measures are immune to such errors because it measures ongoing processes.

The present study also contributed to clarifying the relationship between decision process and decision preference. On the one hand, both decision preference and decision process were affected by certain contextual settings, such as gain-loss manipulation. Moreover, it was found that the variation of decision process was related to the final choice outcome. In the present study, participants experienced more conflict and uncertainty when selecting the long-term advantageous option in the intertemporal choice task, when selecting the riskier gain and safer loss in the gain choice task, and when choosing the more expensive hotel in the consumer choice task. The results demonstrated that the cognitive processes were different when making different choices. The preference in intertemporal choice has long been connected with the concept of self-control (for a review, see de Wit, 2008). The current work extended the meaning of self-control. That is, participants had to overcome the experienced conflict and uncertainty in order to choose the long-term advantageous option.

On the other hand, however, there was also evidence showing that decision process was independent of decision preference. In Experiment 3 where the importance of task was manipulated, participants showed stronger preference toward the more-expensive hotel in the more-important condition because in this condition, participants' family members were supposed to come to celebrate their graduation. In other words, celebration with family members provided a persuasive reason to choose a better but more expensive hotel. However, the experience of conflict and uncertainty did not decrease when the persuasive reason was available, implying that it was still difficult for participants to choose the more expensive hotel, possibly due to their financial affordability. Taken together, the results indicated that the relationship between decision process and decision preference was complicated. Decision preference was not necessarily informative about decision process. Hence, the study highlights the necessity to study decision process, particularly the experience when making decisions in future research.

In addition to the contextual factors, the present study also examined the role of an internal cognitive ability, numeracy, in decision difficulty. Across three experiments, numeracy was negatively related to Idle time and the Conflict component. The finding implied that people with poorer numerical ability needed more time to process choice information and had more conflicting experience.

The present study uncovers the difficulty experience during the processes when making decisions. In particular, the study connects the experience of difficulty and particular decision contexts. Although the present study employs hypothetical options, implications for practical activities in daily life can be generated. For example, the present study reveals that participants experienced more difficulty (demonstrated by both trajectory pattern and self-report) when options had similar attributes. Therefore, the study indicates that to facilitate decision making, similar options should be avoided to being presented together. Meanwhile, the study also shows that numeracy is related to decision difficulty. Hence, presenting options with massive numerical values may confuse decision makers. For instance, a number of shopping websites tend to present their items simultaneously in a long list (sometimes even after applying the filter function). These items contains a series of numbers, such as price, rating, physical properties, financial information (e.g., interest rate) and so forth. Consumers, particularly for those with lower numeracy, may get overwhelmed by the numerical information presented. Booking.com is a popular website where consumers can choose which hotel to stay. In addition to presenting customers' rating (ranging from 0-10) for hotels, it also divide the rating scale into different yet conceptually meaningful categories. For example, a rating between 9-10 is labeled superb, and a rating between 8-10 is labeled very good. Thus, consumers may use qualitative categories to avoid confusion from numbers.

The study is among a few using action dynamics to investigate decision processes. Although the study tests intertemporal, gamble and consumer choices with different contexts, the results and implications are by no means exhaustive. Some limitations should be addressed before a conclusion can be made. First, the study, as well as many others, adopts binary choice as the paradigm. Nonetheless, in daily life, decisions need to be made among multiple options are possible. For example, when choosing hotels, regardless of which website the consumers use, they need to pick one from a list. Making choices from multiple options mimics the situations in real life, however, the program that tracks trajectory needs to be rewritten in order to accommodate the stimuli presentation and measures calculation. For example, when presenting a list of five options, the start point is more difficult to be specified. Relatedly, the current work is completed with data acquired from traditional lab behavioral experiments. As the big data era is coming, the methodology of action dynamics could further increase its validity if the data could be collected online from real decision environment. Mobile devices, such as smartphone and pad, can further provide a convenient platform to collect data. Again, employing different ways to collect data demands to further improve the trajectory program. Second, the study consistently finds that choosing different options is associated with different trajectory patterns, hence building a relationship between decision preference and decision process. However, the relationship should be explained cautiously, given the possible impact of socio-economic status. As discussed, the participants in the present study are college students to whom affordability is a great concern. Hence, they experience more difficulty when choosing the later larger gains in the intertemporal choice task, and more expensive hotels in the consumer choice task. The present study implies that the processes are different when selecting different options. Future studies should further take socio-economic status into account when dealing decision processes in economic decisions.

In conclusion, the present study demonstrates that decision difficulty is a multi-dimensional construct. Both conflict and uncertainty are important sources for decision difficulty. The study further advances the knowledge of using dynamic and online measures to study the behavior of decision-making. Traditional studies normally employed self-reported scales to measure psychological experiences. The present study further illustrates that the experiences during decision process can be depicted by dynamic behavioral measures generated from mouse-tracking. Over the past decades, majority of studies in the field of decision-making focus on choice preference, and examine choice preference from the perspective of external and internal factors. The present study illustrate a new direction in which choice preference can be investigated from the aspect of decision process, because the psychological experience varies when making different choices.

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Appendix A: Numeracy Scale and Locomotion Scale

Numeracy Scale (*with keys, answers do not appear in the scale for participants*)

1. Imagine that we roll a fair, six-sided die 1,000 times. Out of 1,000 rolls, how many times do you think the die would come up as an even number?
Answer: Half the time, 50%, any number between 490-510, 1:2

2. In the BIG BUCKS LOTTERY, the chances of winning a $10.00 prize are 1%. What is your best guess about how many people would win a $10.00 prize if 1,000 people each buy a single ticket from BIG BUCKS?
Answer: ___10__people

3. In the ACME PUBLISHING SWEEPSTAKES, the chance of winning a car is 1 in 1,000. What percent of tickets of ACME PUBLISHING SWEEPSTAKES win a car?
Answer: ___.1__%

4: If the chance of getting a disease is 10%, how many people would be expected to get the disease? Out of 1000?
Answer: __100___people

5. If the chance of getting a disease is 20 out of 100, this would be the same as having a __20__% chance of getting the disease.

6. Suppose you have a close friend who has a lump in her breast and must have a mammogram. Of 100 women like her, 10 of them actually have a malignant tumor and 90 of them do not. Of the 10 women who actually have a tumor, the mammogram indicates correctly that 9 of them have a tumor and indicates incorrectly that 1 of them does not have a tumor. Of the 90 women who do not have a tumor, the mammogram indicates correctly that 81 of them do not have a tumor and indicates incorrectly that 9 of them do have a tumor. The table below summarizes all of this information. Imagine that your friend tests positive (as if she had a tumor), what is the likelihood that she actually has a tumor?

	Tested Positive	Tested Negative	Totals
Actually has a tumor	9	1	10
Does not have a tumor	9	81	90
Totals	18	82	100

Answer: __9___ out of __18___

7. A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?
Answer: __5___cents

8. In a lake, there is a patch of lilypads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?
Answer: __47___day

Locomotion scale

Read each of the following statements and decide how much you agree with each according
to your beliefs and experiences. Please respond according to the following scale:

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1 = strongly disagree	4 = slightly agree
2 = moderately disagree	5 = moderately agree
3 = slightly disagree	6 = strongly agree

----

1. I don’t mind doing things even if they involve extra effort.
2. I am a “workaholic.”
3. I feel excited just before I am about to reach a goal.
4. I enjoy actively doing things, more than just watching and observing.
5. I am a “doer.”
6. When I finish one project, I often wait awhile before getting started on a new one.
7. When I decide to do something, I can’t wait to get started.
8. By the time I accomplish a task, I already have the next one in mind.
9. I am a “low energy” person.
10. Most of the time my thoughts are occupied with the task that I wish to accomplish.
11. When I get started on something, I usually persevere until I finish.
12. I am a “go-getter.”

Appendix B: Choice Stimuli in Experiments 1, 2 and 3

Table B1

Choice pairs in the intertemporal choice task in Experiments 1and 2 (less-similar context)

Trial	Larger magnitude ($)	Longer delay (days)	Smaller magnitude ($)	Sooner delay (days)
1	75	32	55	14
2	600	60	490	40
3	540	28	324	21
4	230	28	190	40
5	370	52	205	60
6	300	20	75	5
7	250	42	176	17
8	600	90	267	40
9	400	80	350	70
10	320	28	242	38
11	430	69	253	82
12	385	33	235	40
13	300	42	233	20
14	650	55	316	35
15	445	24	365	34
16	430	32	280	40
17	330	29	275	42
18	210	43	161	20
19	200	120	127	40
20	450	40	281	25
21	320	35	240	47
22	600	65	288	41
23	225	33	170	15
24	425	65	311	28
25	650	48	190	14
26	260	42	172	53
27	280	55	163	65
28	700	40	420	30
29	600	80	285	50
30	900	80	315	28
31	315	67	188	30
32	125	26	76	12
33	150	20	38	8
34	49	15	28	4

Table B1: continued

35	550	31	166	14
36	260	30	180	39
37	430	20	301	14
38	450	40	293	20
39	290	70	209	40
40	290	50	102	10
41	480	90	141	40
42	225	52	159	29
43	400	60	207	40
44	240	56	135	23
45	270	26	206	12
46	328	31	258	43
47	260	55	156	33
48	330	69	215	45
49	400	20	80	7
50	450	50	90	10
51	460	54	278	65
52	330	70	288	40
53	150	64	95	31
54	405	43	174	12
55	485	31	405	44

In the intertemporal choice task, take the first choice pair as an example, in the gain condition, the sooner option is expressed as "Receiving $55 in 14 days", and the later option is expressed as "Receiving $75 in 32 days". In the loss condition, the sooner option is expressed as "Paying $55 in 14 days", and the later option is expressed as "Paying $75 in 32 days".

Table B2

Choice pairs in the intertemporal choice task in the more-similar context in Experiment 2

Trial	Larger magnitude ($)	Longer delay (days)	Smaller magnitude ($)	Sooner delay (days)
1	69	27	61	19
2	567	54	523	46
3	475	26	389	23
4	218	32	202	36
5	321	54	255	58
6	233	16	143	10
7	228	35	198	25
8	500	75	367	55
9	385	77	365	73
10	297	31	265	35
11	377	73	306	78
12	340	35	280	38
13	280	35	253	27
14	550	49	416	41
15	421	27	389	31
16	385	34	325	38
17	314	33	292	38
18	195	36	176	27
19	178	96	149	64
20	399	36	332	30
21	296	39	264	44
22	506	58	382	48
23	209	28	187	20
24	391	54	345	39
25	512	38	328	24
26	234	45	198	50
27	245	58	198	62
28	616	37	504	33
29	506	71	380	59
30	725	64	491	44
31	277	56	226	41
32	110	22	91	16
33	116	16	72	12
34	43	12	34	7
35	435	26	281	19
36	236	33	204	36
37	391	18	340	16
38	403	34	340	26

Table B2: continued

39	266	61	233	49
40	234	38	158	22
41	378	75	243	55
42	205	45	179	36
43	342	54	265	46
44	209	46	167	33
45	251	22	225	16
46	307	35	279	39
47	229	48	187	40
48	296	62	250	52
49	304	16	176	11
50	342	38	198	22
51	405	57	333	62
52	317	61	301	49
53	134	54	112	41
54	336	34	243	21
55	461	35	429	40

Table B3

Choice pairs in the gamble choice task in Experiments 1and 2 (less-similar context)

Trial	Larger magnitude ($)	Riskier Probability	Smaller magnitude ($)	Safer Probability
1	660	0.40	576	0.70
2	225	0.36	135	0.48
3	445	0.51	93	0.38
4	250	0.78	39	0.56
5	500	0.07	356	0.17
6	125	0.27	66	0.40
7	320	0.71	67	0.53
8	450	0.10	158	0.50
9	550	0.14	249	0.31
10	425	0.25	84	0.72
11	540	0.12	471	0.21
12	400	0.70	409	0.80
13	600	0.40	356	0.90
14	330	0.48	17	0.32
15	850	0.28	622	0.65
16	400	0.40	267	0.60
17	450	0.25	350	0.40
18	600	0.41	379	0.65
19	700	0.30	525	0.40
20	250	0.22	46	0.66
21	150	0.08	60	0.20
22	240	0.50	72	0.40
23	400	0.07	140	0.20
24	150	0.39	72	0.62
25	310	0.58	31	0.40
26	380	0.54	123	0.44
27	460	0.71	119	0.55
28	205	0.63	59	0.50
29	450	0.04	315	0.10
30	430	0.43	70	0.31
31	300	0.05	121	0.20
32	260	0.67	7	0.44
33	100	0.28	69	0.73
34	650	0.20	479	0.34
35	308	0.82	63	0.61
36	700	0.28	349	0.80
37	480	0.40	213	0.90
38	600	0.20	480	0.40

Table B3: continued

39	430	0.14	366	0.20
40	230	0.55	55	0.42
41	290	0.16	93	0.34
42	290	0.33	144	0.51
43	800	0.40	775	0.60
44	600	0.50	375	0.80
45	220	0.66	62	0.52
46	600	0.11	137	0.29
47	330	0.45	265	0.69
48	225	0.28	109	0.44
49	240	0.43	155	0.54
50	260	0.33	195	0.55
51	420	0.11	267	0.33
52	380	0.67	47	0.47
53	150	0.06	134	0.10
54	540	0.21	405	0.28
55	650	0.35	413	0.55

In the gamble choice task, take the first choice pair as an example, in the gain condition, the riskier option is expressed as "Winning $660 with a probability of .40", and the safer option is expressed as "Winning $576 with a probability of .70". In the loss condition, the riskier option is expressed as "Losing $660 with a probability of .40", and the safer option is expressed as "Losing $576 with a probability of .60".

Table B4

Choice pairs in the gamble choice task in the more-similar context in Experiment 2

Trial	Larger magnitude ($)	Riskier Probability	Smaller magnitude ($)	Safer Probability
1	635	0.49	601	0.61
2	198	0.4	162	0.44
3	339	0.47	198	0.42
4	187	0.71	103	0.63
5	457	0.1	399	0.14
6	107	0.31	84	0.36
7	244	0.66	143	0.58
8	362	0.22	245	0.38
9	460	0.19	339	0.26
10	323	0.39	186	0.58
11	519	0.15	492	0.18
12	403	0.73	406	0.77
13	527	0.55	429	0.75
14	236	0.43	111	0.37
15	782	0.39	690	0.54
16	360	0.46	307	0.54
17	420	0.3	380	0.36
18	534	0.48	445	0.58
19	648	0.33	578	0.37
20	189	0.35	107	0.53
21	123	0.12	87	0.16
22	190	0.47	122	0.43
23	322	0.11	218	0.16
24	127	0.46	95	0.55
25	226	0.53	115	0.45
26	303	0.51	200	0.47
27	358	0.66	221	0.6
28	161	0.59	103	0.54
29	410	0.06	356	0.08
30	322	0.39	178	0.35
31	246	0.1	174	0.16
32	184	0.6	83	0.51
33	91	0.42	78	0.6
34	599	0.24	530	0.3
35	235	0.76	137	0.67
36	595	0.44	454	0.64
37	400	0.55	293	0.75
38	564	0.26	516	0.34

Table B4: continued

39	411	0.16	385	0.18
40	178	0.51	108	0.46
41	231	0.21	152	0.29
42	246	0.38	188	0.46
43	792	0.46	782	0.54
44	532	0.59	442	0.71
45	173	0.62	109	0.56
46	461	0.16	276	0.24
47	310	0.52	284	0.62
48	190	0.33	144	0.39
49	215	0.46	181	0.51
50	240	0.4	214	0.48
51	374	0.18	313	0.26
52	280	0.61	147	0.53
53	145	0.07	139	0.09
54	500	0.23	446	0.26
55	579	0.41	484	0.49

Table B5

Choice pairs of consumer choice task in Experiment 3 (less-similar context)

Trial in the less-important condition	Trial in the more-important condition	Higher price ($ per night)	Higher rating (out of 100)	Lower price ($ per night)	Lower rating (out of 100)
1	39	105	51	79	28
2	43	179	84	109	68
3	15	50	70	35	42
4	6	99	68	128	54
5	7	155	70	99	59
6	4	85	40	50	16
7	31	100	92	139	82
8	37	55	46	45	42
9	55	76	85	87	55
10	10	155	84	145	62
11	5	69	65	35	46
12	9	79	68	45	46
13	1	125	72	79	38
14	40	89	58	55	24
15	54	90	81	101	50
16	47	89	77	50	36
17	48	91	81	113	60
18	22	75	53	93	39
19	44	109	48	69	21
20	33	79	56	55	33
21	45	95	83	129	71
22	51	45	74	55	54
23	3	59	36	50	34
24	53	67	82	83	60
25	34	199	95	129	81
26	29	100	74	75	48
27	17	69	50	59	48
28	30	169	99	79	36
29	14	99	83	79	50
30	2	139	78	115	72
31	38	109	61	75	48
32	52	55	69	71	55
33	42	199	99	79	59
34	25	100	55	79	32
35	49	125	68	140	42
36	21	89	66	50	50

Table B5: continued

37	27	75	47	60	33
38	41	129	89	109	66
39	32	129	68	69	23
40	19	125	68	65	22
41	8	120	84	155	67
42	20	129	78	75	38
43	26	99	73	50	44
44	23	129	77	69	49
45	36	109	83	55	58
46	11	109	48	55	34
47	46	145	69	100	41
48	24	99	87	59	61
49	50	99	72	45	40
50	18	159	80	99	34
51	12	109	70	123	44
52	16	135	68	49	38
53	13	67	46	88	37
54	35	120	56	70	44
55	28	98	77	120	56

In the consumer choice task, take the first choice pair as an example, the hotel option is expressed as "The rating of the hotel is 51 out of 100, and its price is $105 per night".

Table B6

Choice pairs of consumer choice task in Experiment 3 (more-similar context)

Trial in the less-important condition	Trial in the more-important condition	Higher price ($ per night)	Higher rating (out of 100)	Lower price ($ per night)	Lower rating (out of 100)
1	39	97	44	87	35
2	43	158	79	130	73
3	15	46	62	40	50
4	6	108	64	119	58
5	7	138	67	116	62
6	4	75	33	61	23
7	31	112	89	127	85
8	37	52	45	48	43
9	55	79	76	84	64
10	10	152	77	148	69
11	5	59	59	45	52
12	9	69	61	55	53
13	1	111	62	93	48
14	40	79	48	65	34
15	54	93	72	97	59
16	47	77	65	62	48
17	48	98	75	106	66
18	22	80	49	88	43
19	44	97	40	81	29
20	33	72	49	62	40
21	45	105	79	119	75
22	51	48	68	52	60
23	3	56	35	53	34
24	53	72	75	78	67
25	34	178	91	150	85
26	29	93	66	83	56
27	17	66	49	62	49
28	30	142	80	106	55
29	14	93	73	85	60
30	2	132	76	122	74
31	38	99	57	85	52
32	52	60	65	66	59
33	42	163	87	115	71
34	25	94	48	85	39
35	49	130	60	136	50
36	21	77	61	62	55

Table B6: Continued

37	27	71	43	65	37
38	41	123	82	115	73
39	32	111	55	87	37
40	19	107	54	83	36
41	8	131	79	145	72
42	20	113	66	91	50
43	26	84	64	65	53
44	23	111	69	87	57
45	36	93	76	71	66
46	11	93	44	71	38
47	46	132	61	114	49
48	24	87	79	71	69
49	50	83	62	61	50
50	18	141	66	117	48
51	12	113	62	119	52
52	16	109	59	75	47
53	13	73	43	82	40
54	35	105	52	85	48
55	28	105	71	113	62

Appendix C: Individual Measure Analyses in Experiment 1

Table 5 in the main text shows the means for each measure in each testing condition in both tasks. In the intertemporal choice task, for each measure, a 2 (sign: gain vs. loss) * 3 (selected option: sooner vs. later vs. dominant) repeated-measures ANOVA was conducted on measure values, with sign and selected option as within-subjects factors. Detailed results were listed in Table C1 in appendix. The second column of the Table C1 stated the finding for each test. Although measures were different and might capture different aspects of decision process, there were several common findings across different measures. First, selecting the dominant option led to significantly smaller values in all measures in both gain and loss contexts, when compared to choosing other options. In addition, the process of choosing the dominant option remained constant between the gain and loss contexts. Such findings further implied that the manipulation of dominance was successful, as participants did not have to make any trade-offs when the dominant option was available. Second, except X-flip, choosing the later larger option in the gain context, and choosing the sooner smaller option in the loss context were associated with larger values in the rest of the four measures. Hence, choosing the long-term advantageous options in both gain and loss contexts resulted in longer response times and less straightforward trajectories. Third, as for the sign effect, except X-flip, overall, making decisions in the loss context than in the gain context led to less direct trajectories. The difference between X-flip and other measures suggested that X-flip might not be sensitive to the gain-loss variation in the decision context.

Similar to what was done in the intertemporal choice task, in the gamble choice task, for each measure, a 2 (sign: gain vs. loss) * 3 (selected option: riskier vs. safer vs. dominant) repeated-measures ANOVA was conducted, with sign and selected option as within-subjects factors. Across different measures, there were several common findings. First, similar to the intertemporal choice task, choosing the dominant option always led to shortest response times and most straightforward trajectories, regardless of the sign of the context. Second, choosing the riskier option in the gain context, and choosing the safer option in the loss context were related to longer times and less direct trajectories. Third, Idle time, X-flip and AAD showed larger values in the loss context than in the gain context, regardless of whether the riskier option or the safer option was chosen. Distance and Motion time captured such an effect only when the safer option was selected. More detailed results are found in Table C2.

Table C1

Effects of sign, what was selected and dominance on each measure in gamble choice task

Measure	Finding	Test result
Idle time	Interaction between sign and selected option was significant	*F*(2,44) = 84.09, $p < .001$, partial $\eta 2 = .79$, *Wilks' Λ* = .21
	Main effect of sign was significant	*F*(1,45) = 90.62, $p < .001$, partial $\eta 2$=.69, *Wilks' Λ* = .31
	Main effect of selected option was significant	*F*(2,44) = 2210, $p < .001$, partial $\eta 2 = .99$, *Wilks' Λ* = .01
	In the gain context, choosing the later larger gain over the sooner smaller one led to longer idle time	*F*(1,45) = 36.26, $p < .001$, partial $\eta 2 = .45$
	In the loss context, choosing the sooner smaller loss was associated with longer idle time	*F*(1,45) = 19.98, $p < .001$, partial $\eta 2 = .31$
	Choosing the dominant option (when it was available) led to significantly shorter idle time than when choosing other types of options (when the dominant option was not available)	*F*(1,45) ≥ 960, *p*-values < .001, partial $\eta 2 \geq .96$
	It took longer idle time to choose the sooner option in the loss context than in the gain context	*F*(1,45) = 193.8, $p < .001$, partial $\eta 2 = .81$
	It took longer idle time to choose the later option in the loss context than in the gain context	*F*(1,45) = 6.78, $p = .012$, partial $\eta 2 = .13$
	Choosing the dominant option was not affected by the sign of the context	*F*(1,45) = 2.03, $p = .161$, partial $\eta 2 = .04$
Motion time	Interaction between sign and selected option was significant	*F*(2,44) = 35.63, $p < .001$, partial $\eta 2$=.62, *Wilks' Λ* = .38
	Main effect of sign was significant	*F*(1,45) = 15.95, $p < .001$, partial $\eta 2$=.26, *Wilks' Λ* = .74
	Main effect of selected option was significant	*F*(2,44) = 2975.5, $p < .001$, partial $\eta 2$=.99, *Wilks' Λ* = .007

Table C1: continued

	In the gain context, choosing the later larger gain over the sooner smaller one led to longer motion time	$F(1,45) = 18.32$, $p < .001$, partial $\eta 2 = .29$
	In the loss context, choosing the sooner smaller loss was associated with longer motion time	$F(1,45) = 44.85$, $p < .001$, partial $\eta 2 = .50$
	Choosing the dominant option led to significantly shorter motion time than when choosing other types of options	$F(1,45) \geq 1328$, p-values < .001, partial $\eta 2 \geq .97$
	It took longer motion time to choose the sooner option in the loss context than in the gain context	$F(1,45) = 76.16$, $p < .001$, partial $\eta 2 = .63$
	It took longer motion time to choose the later option in the loss context than in the gain context	$F(1,45) = 4.59$, $p = .038$, partial $\eta 2 = .09$
	Choosing the dominant option was not affected by the sign of the context	$F(1,45) = 2.65$, $p = .110$, partial $\eta 2 = .06$
Distance	Interaction between sign and selected option was significant	$F(2,44) = 34.39$, $p < .001$, partial $\eta 2$=.61, *Wilks' Λ* = .39
	Main effect of sign was significant	$F(1,45) = 25.12$, $p < .001$, partial $\eta 2$=.36, *Wilks' Λ* = .64
	Main effect of selected option was significant	$F(2,44) = 1400$, $p < .001$, partial $\eta 2$=.99, *Wilks' Λ* = .02
	In the gain context, choosing the later larger gain over the sooner smaller one led to longer travelled distance	$F(1,45) = 13.11$, $p = .001$, partial $\eta 2$=.23
	In the loss context, choosing the sooner smaller loss was associated with longer distance	$F(1,45) = 37.03$, $p < .001$, partial $\eta 2$=.45
	Choosing the dominant option led to significantly shorter distance than when choosing other types of options	$F(1,45) \geq 478$, p-values < .001, partial $\eta 2 \geq .91$
	The distance was longer in the loss context than in the gain context when choosing the sooner option	$F(1,45) = 69.34$, $p < .001$, partial $\eta 2$=.36
	The distance did not vary significantly between the gain and loss contexts when choosing the later option	$F(1,45) = 1.49$, $p = .228$, partial $\eta 2$=.03

Table C1: continued

	Choosing the dominant option was not affected by the sign of the context	F(1,45) = .60, p = .444, partial $\eta 2$ = .01
X-flip	Interaction between sign and selected option was not significant	F(2,44) = 2.86, p = .068, partial $\eta 2$=.12, *Wilks' Λ* = .89
	Main effect of sign was not significant	F(1,45) = 2.20, p = .145, partial $\eta 2$=.05, *Wilks' Λ* = .95
	Main effect of selected option was significant	F(2,44) = 2289, p < .001, partial $\eta 2$=.99, *Wilks' Λ* = .01
	No significant difference between when choosing the sooner option and when choosing the later option	F(1,45) = .36, p = .55, partial $\eta 2$ = .008
	Choosing the dominant option led to significantly shorter distance than when choosing other types of options	F(1,45) ≥ 2403, p-values < .001, partial $\eta 2$ ≥ .98
AAD	Interaction between sign and selected option was significant	F(2,44) = 44.48, p < .001, partial $\eta 2$=.67, *Wilks' Λ* = .33
	Main effect of sign was significant	F(1,45) = 50.40, p < .001, partial $\eta 2$=.53, *Wilks' Λ* = .47
	Main effect of selected option was significant	F(2,44) = 449, p < .001, partial $\eta 2$=.95, *Wilks' Λ* = .05
	In the gain context, choosing the later larger gain over the sooner smaller one led to larger deviation	F(1,45) = 14.57, p = .001, partial $\eta 2$=.25
	In the loss context, choosing the sooner smaller loss was associated with larger deviation	F(1,45) = 16.02, p < .001, partial $\eta 2$=.26
	Choosing the dominant option led to significantly smaller deviation than when choosing other types of options	F(1,45) ≥ 152, p-values < .001, partial $\eta 2$ ≥ .77
	The deviation was larger in the loss context than in the gain context when choosing the sooner option	F(1,45) = 86.32, p < .001, partial $\eta 2$=.36,
	The deviation did not vary significantly between the gain and loss contexts when choosing the later option	F(1,45) = .10, p = .760, partial $\eta 2$=.002

Table C1: continued

	Choosing the dominant option was not affected by the sign of the context	$F(1,45) = .68$, $p = .415$, partial $\eta 2 = .02$

Note. Tests that failed to reach $p = .05$ were omitted from the table (i.e., no other main effects or interactions were significant for any measure).

Table C2

Effects of sign, what was selected and dominance on each measure in gamble choice task

Measure	Finding	Test result
Idle time	Interaction between sign and choice type was significant	$F(2,46) = 81.67$, $p < .001$, partial $\eta 2 = .78$, *Wilks' Λ* = .22
	Main effect of sign was significant	$F(1,47) = 104.77$, $p < .001$, partial $\eta 2$=.69, *Wilks' Λ* = .31
	Main effect of choice type was significant	$F(2,46) = 8228$, $p < .001$, partial $\eta 2 = .99$, *Wilks' Λ* = .003
	In the gain context, choosing the riskier gain over the safer one led to longer idle time	$F(1,47) = 4.86$, $p = .032$, partial $\eta 2 = .09$
	In the loss context, choosing the safer loss was associated with longer idle time	$F(1,47) = 21.36$, $p < .001$, partial $\eta 2 = .31$
	Choosing the dominant option led to significantly shorter idle time than when choosing other types of options	$F(1,47) \geq 2767$, p-values < .001, partial $\eta 2 \geq .98$
	It took longer idle time to choose the riskier option in the loss context than in the gain context	$F(1,47) = 21.18$, $p < .001$, partial $\eta 2 = .31$
	It took longer idle time to choose the safer option in the loss context than in the gain context	$F(1,47) = 164.93$, $p = .012$, partial $\eta 2 = .78$
	Choosing the dominant option was not affected by the sign of the context	$F(1,47) = .20$, $p = .657$, partial $\eta 2 = .004$
Motion time	Interaction between sign and choice type was significant	$F(2,46) = 21.04$, $p < .001$, partial $\eta 2 = .48$, *Wilks' Λ* = .52
	Main effect of sign was significant	$F(1,47) = 14.57$, $p < .001$, partial $\eta 2$=.24, *Wilks' Λ* = .76
	Main effect of choice type was significant	$F(2,46) = 1402$, $p < .001$, partial $\eta 2 = .98$, *Wilks' Λ* = .02
	In the gain context, choosing the riskier gain over the sooner smaller one led to longer motion time	$F(1,47) = 6.84$, $p = .012$, partial $\eta 2 = .013$

Table C2: continued

	In the loss context, choosing the safer loss was associated with longer motion time	$F(1,47) = 7.33$, $p = .009$, partial $\eta 2 = .13$
	Choosing the dominant option led to significantly shorter motion time than when choosing other types of options	$F(1,47) \geq 814$, p-values < .001, partial $\eta 2 \geq .95$
	When choosing the riskier option, motion time did not vary significantly between gain and loss contexts	$F(1,47) = 1.23$, $p = .273$, partial $\eta 2 = .03$
	It took longer motion time to choose the safer option in the loss context than in the gain context	$F(1,47) = 42.77$, $p < .001$, partial $\eta 2 = .48$
	Choosing the dominant option was not affected by the sign of the context	$F(1,47) = 2.08$, $p = .156$ partial $\eta 2 = .04$
Distance	Interaction between sign and choice type was significant	$F(2,46) = 20.69$, $p < .001$, partial $\eta 2 = .47$, *Wilks' Λ* = .53
	Main effect of sign was significant	$F(1,47) = 39.80$, $p < .001$, partial $\eta 2$=.46, *Wilks' Λ* = .54
	Main effect of choice type was significant	$F(2,46) = 1209$, $p < .001$, partial $\eta 2 = .98$, *Wilks' Λ* = .02
	In the gain context, choosing the riskier gain over the sooner smaller one led to longer travelled distance	$F(1,47) = 20.76$, $p < .001$, partial $\eta 2 = .31$
	In the loss context, there was no significant difference in travelled when choosing different options	$F(1,47) = 3.47$, $p = .07$, partial $\eta 2 = .07$
	Choosing the dominant option led to significantly shorter distance than when choosing other types of options	$F(1,47) \geq 611$, p-values < .001, partial $\eta 2 \geq .93$
	The distance remained constant between gain and loss contexts when choosing the riskier option	$F(1,47) = 1.13$, $p = .290$, partial $\eta 2 = .02$
	The distance was longer in the loss than in the gain context when choosing the safer option	$F(1,47) = 39.35$, $p < .001$, partial $\eta 2 = .46$
	Choosing the dominant option was not affected by the sign of the context	$F(1,47) = .65$, $p = .430$, partial $\eta 2 = .01$

Table C2: continued

X-flip	Interaction between sign and choice type was significant	$F(2,46) = 16.02$, $p < .001$, partial $\eta 2 = .41$, *Wilks' Λ* = .59
	Main effect of sign was significant	$F(1,47) = 35.37$, $p < .001$, partial $\eta 2$=.43, *Wilks' Λ* = .57
	Main effect of choice type was significant	$F(2,46) = 1363$, $p < .001$, partial $\eta 2 = .98$, *Wilks' Λ* = .02
	Choosing the riskier option in the gain context led to more x-flips	$F(1,47) = 10.63$, $p = .002$, partial $\eta 2 = .18$
	Choosing the safer option in the loss context led to more x-flips	$F(1,47) = 5.36$, $p = .025$, partial $\eta 2 = .10$
	Choosing the dominant option led to significantly shorter distance than when choosing other types of options	$F(1,47) \geq 683$, p-values < .001, partial $\eta 2 \geq .94$
	There were more x-flips in the loss context when choosing the riskier option	$F(1,47) = 19.46$, $p < .001$, partial $\eta 2 = .29$
	There were more x-flips in the loss context when choosing the safer option	$F(1,47) = 30.04$, $p < .001$, partial $\eta 2 = .39$
	Choosing the dominant option was not affected by the sign of the context	$F(1,47) = .25$, $p = .619$, partial $\eta 2 = .01$
AAD	Interaction between sign and choice type was significant	$F(2,46) = 39.40$, $p < .001$, partial $\eta 2 = .63$, *Wilks' Λ* = .37
	Main effect of sign was significant	$F(1,47) = 77.80$, $p < .001$, partial $\eta 2$=.62, *Wilks' Λ* = .38
	Main effect of choice type was significant	$F(2,46) = 1991$, $p < .001$, partial $\eta 2 = .99$, *Wilks' Λ* = .01
	In the gain context, choosing the riskier gain led to larger deviation	$F(1,47) = 6.58$, $p = .014$, partial $\eta 2 = .12$
	In the loss context, choosing the safer was associated with larger deviation	$F(1,47) = 10.06$, $p = .003$, partial $\eta 2 = .18$

Table C2: continued

	Choosing the dominant option led to significantly smaller deviation than when choosing other types of options	$F(1,47) \geq 833$, p-values < .001, partial $\eta 2 \geq .95$
	The deviation was larger in the loss context than in the gain context when choosing the riskier option	$F(1,47) = 10.28$, $p = .002$, partial $\eta 2 = .18$
	The deviation was larger in the loss context than in the gain context when choosing the safer option	$F(1,47) = 68.89$, $p < .001$, partial $\eta 2 = .59$
	Choosing the dominant option was not affected by the sign of the context	$F(1,47) = 1.81$, $p = .185$, partial $\eta 2 = .04$

Note. Tests that failed to reach $p = .05$ were omitted from the table (i.e., no other main effects or interactions were significant for any measure).

Appendix D: Individual Measure Analyses in Experiment 2

Table 12 summarizes the means of each measure in each testing condition in both tasks. Table D1 and Table D2 show the detailed testing results in the intertemporal choice and gamble choice tasks, respectively.

In the intertemporal choice task, for each measure, a 2 (similarity: less-similar vs. more-similar) * 3 (selected option: sooner vs. later vs. dominant) repeated-measures ANOVA was conducted on measure values, with similarity and selected option as within-subjects factors. In general, there were three common findings across different measures. First, choosing the dominant option led to smaller values in all measures, and the process (except travelled distance) did not vary between the less-similar and more similar contexts when choosing the dominant option. Second, when compared to choosing the sooner smaller gain, choosing the later larger gain always led to larger values in all measures, regardless of similarity of the context. Third, Motion time and X-flip displayed larger values in the more-similar context than in the less-similar context, regardless of whether the sooner option or the later option was selected. By contrast, Idle time, Distance, and AAD captured the effect of similarity only when a particular option was chosen. Thus, such a finding implied that different measures had different sensitivities toward the manipulation of similarity.

In the gamble choice task, for each measure, a 2 (similarity: less-similar vs. more-similar) * 3 (selected option: riskier vs. safer vs. dominant) repeated-measures ANOVA was conducted on measure values, with similarity and selected option as within-subjects factors. Similar to the intertemporal choice task, there were some common findings across different measures. First, choosing the dominant option led to smaller values in all measures, and the process (except Motion time) did not vary between the less-similar and more similar contexts when choosing the dominant option. Second, when compared to choosing the safer gain, choosing the riskier gain always led to larger values in all measures, regardless of similarity of the context. Third, all measures increased their values in the more-similar context than in the less-similar context, regardless of which option was chosen (riskier option vs. safer option).

Therefore, both tasks showed that the dominant option led to a unique process which was far different from the one in which trade-offs had to be made. Moreover, the study replicated the choice pattern that choosing the later gain in intertemporal choice and riskier gain in gamble choice was related to longer response times and more deviant trajectories. Most importantly, measures showed varying capacities to capture the similarity effect, indicating that the experience of conflict and uncertainty might be different when facing the more-similar vs. less-similar option pairs.

Table D1

Effects of similarity, what was selected and dominance on each measure in intertemporal choice task

Measure	Finding	Test result
Idle time	Interaction between similarity and selected option was significant	$F(2,44) = 11.73$, $p < .001$, partial $\eta 2 = .35$, *Wilks' Λ* = .65
	Main effect of similarity was significant	$F(1,45) = 5.66$, $p < .001$, partial $\eta 2=.11$, *Wilks' Λ* = .89
	Main effect of selected option was significant	$F(2,44) = 1176$, $p < .001$, partial $\eta 2 = .98$, *Wilks' Λ* = .02
	In the less-similar context, choosing the later option over the sooner one led to longer idle time	$F(1,45) = 17.35$, $p < .001$, partial $\eta 2 = .28$
	In the more-similar context, choosing the later option over the sooner one led to longer idle time	$F(1,45) = 47.72$, $p < .001$, partial $\eta 2 = .52$
	Choosing the dominant option led to significantly shorter idle time than when choosing other types of options	$F(1,47) \geq 404$, p-values < .001, partial $\eta 2 \geq .90$
	When choosing the sooner option, idle time remained constant between the less-similar and more-similar contexts	$F(1,45) = 0.024$, $p =.877$, partial $\eta 2 = .01$
	It took longer idle time to choose the later option in the more-similar context than in the less-similar context	$F(1,45) = 19.82$, $p < .001$, partial $\eta 2 = .31$
	Choosing the dominant option was not affected by the similarity of the context	$F(1,45) = .28$, $p = .599$, partial $\eta 2 = .001$
Motion time	Interaction between similarity and selected option was significant	$F(2,44) = 6.09$, $p < .001$, partial $\eta 2 = .22$, *Wilks' Λ* = .78
	Main effect of similarity was significant	$F(1,45) = 16.08$, $p < .001$, partial $\eta 2=.26$, *Wilks' Λ* = .74
	Main effect of selected option was significant	$F(2,44) = 2817$, $p < .001$, partial $\eta 2 = .99$, *Wilks' Λ* = .008
	In the less-similar context, choosing the later option over the sooner one led to longer motion time	$F(1,45) = 35.79$, $p < .001$, partial $\eta 2 = .44$

Table D1: continued

	In the more-similar context, choosing the later option over the sooner one led to longer motion time	$F(1,45) = 39.54$, $p < .001$, partial $\eta 2 = .47$
	Choosing the dominant option led to significantly shorter motion time than when choosing other types of options	$F(1,47) \geq 751$, p-values < .001, partial $\eta 2 \geq .94$
	It took longer motion time to choose the sooner option in the more-similar context than in the less-similar context	$F(1,45) = 7.83$, $p =.008$, partial $\eta 2 = .15$
	It took longer motion time to choose the later option in the more-similar context than in the less-similar context	$F(1,45) = 6.30$, $p = .016$, partial $\eta 2 = .12$
	Choosing the dominant option was not affected by the similarity of the context	$F(1,45) = .43$, $p = .518$, partial $\eta 2 = .009$
Distance	Interaction between similarity and selected option was significant	$F(2,44) = 7.45$, $p = .002$, partial $\eta 2 = .25$, *Wilks' Λ* = .75
	Main effect of similarity was significant	$F(1,45) = 15.08$, $p < .001$, partial $\eta 2$=.25, *Wilks' Λ* = .75
	Main effect of selected option was significant	$F(2,44) = 1010$, $p < .001$, partial $\eta 2 = .98$, *Wilks' Λ* = .002
	In the less-similar context, choosing the later option over the sooner one led to longer travelled distance	$F(1,45) = 56.01$, $p < .001$, partial $\eta 2 = .55$
	In the more-similar context, choosing the later option over the sooner one led to longer travelled distance	$F(1,45) = 36.17$, $p < .001$, partial $\eta 2 = .45$
	Choosing the dominant option led to significantly shorter motion time than when choosing other types of options	$F(1,47) \geq 333$, p-values < .001, partial $\eta 2 \geq .88$
	Choosing the sooner option in the more-similar context than in the less-similar context led to longer distance	$F(1,45) = 15.16$, $p < .001$, partial $\eta 2 = .25$
	When choosing the later option, the distance remained constant between less-similar and more-similar contexts	$F(1,45) = 3.25$, $p = .078$, partial $\eta 2 = .07$
	Choosing the dominant option in the more-similar context than in the less-similar context led to longer distance	$F(1,45) = 18.49$, $p < .001$, partial $\eta 2 = .29$
X-flip	Interaction between similarity and selected option was significant	$F(2,44) = 72.03$, $p < .001$, partial $\eta 2 = .77$, *Wilks' Λ* = .23

Table D1: continued

	Main effect of similarity was significant	$F(1,45) = 153.97$, $p < .001$, partial $\eta 2$=.77, *Wilks' Λ* = .23
	Main effect of selected option was significant	$F(2,44) = 4534$, $p < .001$, partial $\eta 2 = .99$, *Wilks' Λ* = .005
	Choosing the later option in the less-similar context led to more x-flips	$F(1,45) = 5.49$, $p = .024$, partial $\eta 2 = .11$
	Choosing the later option in the more-similar context led to more x-flips	$F(1,45) = 10.45$, $p = .002$, partial $\eta 2 = .19$
	Choosing the dominant option led to significantly shorter distance than when choosing other types of options	$F(1,45) \geq 1091$, p-values < .001, partial $\eta 2 \geq .96$
	There were more x-flips in the more-similar context when choosing the sooner option	$F(1,45) = 61.77$, $p < .001$, partial $\eta 2 = .58$
	There were more x-flips in the more-similar context when choosing the later option	$F(1,45) = 62.18$, $p < .001$, partial $\eta 2 = .58$
	Choosing the dominant option was not affected by the similarity of the context	$F(1,45) = .14$, $p = .713$, partial $\eta 2 = .003$
AAD	Interaction between similarity and selected option was significant	$F(2,44) = 4.36$, $p = .019$, partial $\eta 2 = .17$, *Wilks' Λ* = .84
	Main effect of similarity was significant	$F(1,45) = 7.62$, $p = .008$, partial $\eta 2$=.15, *Wilks' Λ* = .86
	Main effect of selected option was significant	$F(2,44) = 399$, $p < .001$, partial $\eta 2 = .95$, *Wilks' Λ* = .05
	In the less-similar context, choosing the later option led to larger deviation	$F(1,45) = 12.04$, $p = .001$, partial $\eta 2 = .21$
	In the more-similar context, choosing the later option was associated with larger deviation	$F(1,45) = 22.49$, $p < .001$, partial $\eta 2 = .32$
	Choosing the dominant option led to significantly smaller deviation than when choosing other types of options	$F(1,45) \geq 125$, p-values < .001, partial $\eta 2 \geq .74$

Table D1: continued

	The deviation was larger in the more-similar context than in the less-similar context when choosing the sooner option	$F(1,45) = 6.91$, $p = .012$, partial $\eta 2 = .13$
	The deviation remained constant between the less-similar and more-similar contexts when choosing the later option	$F(1,45) = 1.47$, $p = .23$, partial $\eta 2 = .03$
	Choosing the dominant option was not affected by the similarity of the context	$F(1,45) = .13$, $p = .722$, partial $\eta 2 = .003$

Note. Tests that failed to reach $p = .05$ were omitted from the table (i.e., no other main effects or interactions were significant for any measure).

Table D2

Effects of similarity, what was selected and dominance on each measure in gamble choice task

Measure	Finding	Test result
Idle time	Interaction between similarity and selected option was significant	*F*(2,44) = 13.20, $p < .001$, partial $\eta 2 = .38$, *Wilks' Λ* = .63
	Main effect of similarity was significant	*F*(1,45) = 20.08, $p < .001$, partial $\eta 2$=.31, *Wilks' Λ* = .69
	Main effect of selected option was significant	*F*(2,44) = 2661, $p < .001$, partial $\eta 2 = .99$, *Wilks' Λ* = .01
	In the less-similar context, choosing the riskier option led to longer idle time	*F*(1,45) = 11.28, $p = .002$, partial $\eta 2 = .20$
	In the more-similar context, choosing the riskier option led to longer idle time	*F*(1,45) = 6.51, $p = .014$, partial $\eta 2 = .10$
	Choosing the dominant option led to significantly shorter idle time than when choosing other types of options	*F*(1,47) ≥ 1434, *p*-values < .001, partial $\eta 2 \geq .97$
	It took longer idle time to choose the riskier option in the more-similar context than in the less-similar context	*F*(1,45) =8.47, p =.006, partial $\eta 2 = .16$
	It took longer idle time to choose the safer option in the more-similar context than in the less-similar context	*F*(1,45) = 26.05, $p < .001$, partial $\eta 2 = .16$
	Choosing the dominant option was not affected by the similarity of the context	*F*(1,45) = .44, $p = .511$, partial $\eta 2 = .01$
Motion time	Interaction between similarity and selected option was significant	*F*(2,44) = 16.41, $p < .001$, partial $\eta 2 = .43$, *Wilks' Λ* = .57
	Main effect of similarity was significant	*F*(1,45) = 23.06, $p < .001$, partial $\eta 2$=.34, *Wilks' Λ* = .66
	Main effect of selected option was significant	*F*(2,44) = 3664, $p < .001$, partial $\eta 2 = .99$, *Wilks' Λ* = .006
	In the less-similar context, choosing the riskier option over the sooner one led to longer motion time	*F*(1,45) = 15.56, $p < .001$, partial $\eta 2 = .26$

Table D2: continued

	In the more-similar context, choosing the riskier option over the sooner one led to longer motion time	$F(1,45) = 5.91$, $p = .019$, partial $\eta 2 = .12$
	Choosing the dominant option led to significantly shorter motion time than when choosing other types of options	$F(1,47) \geq 1361$, p-values $< .001$, partial $\eta 2 \geq .97$
	It took longer motion time to choose the riskier option in the more-similar context than in the less-similar context	$F(1,45) = 9.69$, $p = .003$, partial $\eta 2 = .18$
	It took longer motion time to choose the safer option in the more-similar context than in the less-similar context	$F(1,45) = 18.77$, $p < .001$, partial $\eta 2 = .29$
	It took longer motion time to choose the dominant option in the more-similar context than in the less-similar context	$F(1,45) = 4.85$, $p = .033$, partial $\eta 2 = .10$
Distance	Interaction between similarity and selected option was significant	$F(2,44) = 36.75$, $p < .001$, partial $\eta 2 = .63$, *Wilks' Λ* = .37
	Main effect of similarity was significant	$F(1,45) = 73.28$, $p < .001$, partial $\eta 2$=.62, *Wilks' Λ* = .38
	Main effect of selected option was significant	$F(2,44) = 1405$, $p < .001$, partial $\eta 2 = .99$, *Wilks' Λ* = .02
	In the less-similar context, choosing the riskier option over the sooner one led to longer travelled distance	$F(1,45) = 29.82$, $p < .001$, partial $\eta 2 = .40$
	In the more-similar context, choosing the safer option over the sooner one led to longer travelled distance	$F(1,45) = 22.42$, $p < .001$, partial $\eta 2 = .33$
	Choosing the dominant option led to significantly shorter distance than when choosing other types of options	$F(1,47) \geq 390$, p-values $< .001$, partial $\eta 2 \geq .90$
	Choosing the riskier option in the more-similar context than in the less-similar context led to longer distance	$F(1,45) = 33.96$, $p < .001$, partial $\eta 2 = .43$
	Choosing the safer option in the more-similar context than in the less-similar context led to longer distance	$F(1,45) = 26.90$, $p <. 001$, partial $\eta 2 = .37$
	Choosing the dominant option was not affected by similarity in the context	$F(1,45) = .61$, $p = .44$, partial $\eta 2 = .01$
X-flip	Interaction between similarity and selected option was significant	$F(2,44) = 20.94$, $p < .001$, partial $\eta 2 = .49$, *Wilks' Λ* = .51

Table D2: continued

	Main effect of similarity was significant	$F(1,45) = 42.98$, $p < .001$, partial $\eta 2$=.49, *Wilks' Λ* = .51
	Main effect of selected option was significant	$F(2,44) = 1322$, $p < .001$, partial $\eta 2 = .98$, *Wilks' Λ* = .02
	In the less-similar context, choosing the riskier option led to more x-flips	$F(1,45) = 19.17$, $p < .001$, partial $\eta 2 = .30$
	In the more-similar context, choosing the safer option led to more x-flips	$F(1,45) = 10.76$, $p = .002$, partial $\eta 2 = .19$
	Choosing the dominant option led to significantly shorter distance than when choosing other types of options	$F(1,45) \geq 608$, p-values < .001, partial $\eta 2 \geq .93$
	There were more x-flips in the more-similar context when choosing the riskier option	$F(1,45) = 34.89$, $p < .001$, partial $\eta 2 = .44$
	There were more x-flips in the more-similar context when choosing the safer option	$F(1,45) = 38.97$, $p < .001$, partial $\eta 2 = .46$
	Choosing the dominant option was not affected by the similarity of the context	$F(1,45) = .04$, $p = .846$, partial $\eta 2 = .001$
AAD	Interaction between similarity and selected option was significant	$F(2,44) = 12.54$, $p < .001$, partial $\eta 2 = .36$, *Wilks' Λ* = .64
	Main effect of similarity was significant	$F(1,45) = 20.57$, $p = .008$, partial $\eta 2$=.31, *Wilks' Λ* = .69
	Main effect of selected option was significant	$F(2,44) = 1396$, $p < .001$, partial $\eta 2 = .98$, *Wilks' Λ* = .02
	In the less-similar context, choosing the riskier option led to larger deviation	$F(1,45) = 14.64$, $p < .001$, partial $\eta 2 = .25$
	In the more-similar context, choosing the safer option was associated with larger deviation	$F(1,45) = 5.13$, $p = .028$, partial $\eta 2 = .10$
	Choosing the dominant option led to significantly smaller deviation than when choosing other types of options	$F(1,45) \geq 556$, p-values < .001, partial $\eta 2 \geq .93$
	The deviation was larger in the more-similar context than in the less-similar context when choosing the riskier option	$F(1,45) = 4.86$, $p = .033$, partial $\eta 2 = .10$

Table D2: continued

	The deviation was larger in the more-similar context than in the less-similar context when choosing the safer option	$F(1,45) = 16.25$, $p < .001$, partial $\eta2 = .26$
	Choosing the dominant option was not affected by the similarity of the context	$F(1,45) = .62$, $p = .436$, partial $\eta2 = .01$

Note. Tests that failed to reach $p = .05$ were omitted from the table (i.e., no other main effects or interactions were significant for any measure).

Appendix E: Individual Measure Analyses in Experiment 3

Table 19 shows the means for each measure in all testing conditions. For each measure, a 2 (similarity, less-similar vs. more-similar)* 2(importance: less-important vs. more important) * 3 (selected option, cheaper vs. more expensive vs. dominant) repeated-measures ANOVA was performed on measure values, with similarity, importance and selected option as within-subjects factors. Simple tests were employed to unpack the significant interaction, if available. Detailed testing results are found in Table E1. There were two common findings across different measures. First, all measures displayed a significant effect in terms of what was selected. That is, regardless of the manipulation of similarity and importance, choosing the more expensive hotels always led to longest time reactions and least straightforward trajectories. Further regardless of similarity and importance, choosing the dominant option resulted in smallest values in action dynamic measures when compared to choosing the other options. Second, Distance and X-flips captured the effect of similarity by showing larger values in the more-similar context. By contrast, the effect of task importance was not significant.

Table E1

Effects of similarity, importance, what was selected and dominance on each measure in consumer choice task

Measure	Finding	Test result
Idle time	Main effect of choice was significant	$F(2,100) = 5710$, $p < .001$, partial $\eta 2 = .99$, $Wilks' \Lambda = .004$
	Choosing the more expensive hotel took longer Idle time than choosing the cheaper hotel	$F(1,50) = 146.5$, $p < .001$, partial $\eta 2 = .75$
	Choosing the more expensive hotel took longer Idle time than choosing the dominant option	$F(1,50) = 5664$, $p < .001$, partial $\eta 2 = .99$
	Choosing the cheaper hotel took longer Idle time than choosing the dominant option	$F(1,50) = 7172$, $p < .001$, partial $\eta 2 = .99$
Motion time	Main effect of choice was significant	$F(2,100) = 2381$, $p < .001$, partial $\eta 2 = .99$, $Wilks' \Lambda = .007$
	Choosing the more expensive hotel took longer Motion time than choosing the cheaper hotel	$F(1,50) = 100.3$, $p < .001$, partial $\eta 2 = .68$
	Choosing the more expensive hotel took longer Motion time than choosing the dominant option	$F(1,50) = 1704$, $p < .001$, partial $\eta 2 = .99$
	Choosing the cheaper hotel took longer Motion time than choosing the dominant option	$F(1,50) = 4207$, $p < .001$, partial $\eta 2 = .98$
Distance	Interaction between similarity and choice was significant	$F(2,100) = 4.83$, $p = .012$, partial $\eta 2 = .17$, $Wilks' \Lambda = .84$
	Main effect of similarity was significant	$F(1,50) = 11.59$, $p = .001$, partial $\eta 2 = .19$, $Wilks' \Lambda = .81$
	Main effect of choice was significant	$F(2,100) = 1802$, $p < .001$, partial $\eta 2 = .99$, $Wilks' \Lambda = .01$
	The Distance was longer when choosing the more expensive hotel than when choosing the cheaper hotel	$F(1,50) = 125.6$, $p < .001$, partial $\eta 2 = .72$

Table E1: continued

	The Distance was longer when choosing the more expensive hotel than when choosing the dominant option	$F(1,50) = 1928$, $p < .001$, partial $\eta2 = .98$
	The Distance was longer when choosing the cheaper hotel than when choosing the dominant option	$F(1,50) = 2033$, $p < .001$, partial $\eta2 = .99$
	When choosing cheaper hotel, Distance was constant between the more-similar condition and less-similar condition	$F(1,50) = 1.92$, $p = .172$, partial $\eta2 = .04$
	When choosing more expensive hotel, Distance was longer in the more-similar condition than in the less-similar condition	$F(1,50) = 9.37$, $p = .004$, partial $\eta2 = .16$
	When choosing dominant option, Distance was constant between the more-similar condition and less-similar condition	$F(1,50) = 1.35$, $p = .251$, partial $\eta2 = .03$
X-flip	Interaction between similarity and choice was significant	$F(2,100) = 17.02$, $p < .001$, partial $\eta2 = .41$, *Wilks' Λ* = .59
	Main effect of similarity was significant	$F(1,50) = 18.27$, $p < .001$, partial $\eta2 = .27$, *Wilks' Λ* = .73
	Main effect of choice was significant	$F(2,100) = 945$, $p < .001$, partial $\eta2 = .98$, *Wilks' Λ* = .03
	Choosing the more expensive hotel led more flips than choosing the cheaper hotel	$F(1,50) = 113.7$, $p < .001$, partial $\eta2 = .70$
	Choosing the more expensive hotel led more flips than choosing the dominant option	$F(1,50) = 1702$, $p < .001$, partial $\eta2 = .97$
	Choosing the cheaper hotel led more flips than choosing the dominant option	$F(1,50) = 1882$, $p < .001$, partial $\eta2 = .97$
	When choosing cheaper hotel, there were marginally more flips in the more-similar condition than in the less-similar condition	$F(1,50) = 3.95$, $p = .067$, partial $\eta2 = .07$
	When choosing the more expensive hotel, there were more flips in the more-similar condition than in the less-similar condition	$F(1,50) = 30.11$, $p < .001$, partial $\eta2 = .38$
	When choosing the dominant option, the direction flips were not affected by similarity	$F(1,50) = .11$, $p = .747$, partial $\eta2 = .002$
AAD	Main off of choice was significant	$F(1,50) = 3460$, $p < .001$, partial $\eta2 = .99$, *Wilks' Λ* = .008

Table E1: continued

	Choosing the more expensive hotel led to more deviation than choosing the cheaper hotel	$F(1,50) = 115.6$, $p < .001$, partial $\eta 2 = .70$
	Choosing the more expensive hotel led to more deviation than choosing the dominant option	$F(1,50) = 4134$, $p < .001$, partial $\eta 2 = .98$
	Choosing the cheaper hotel led to more deviation than choosing the dominant option	$F(1,50) = 2611$, $p < .001$, partial $\eta 2 = .98$

Note. Tests that failed to reach $p = .05$ were omitted from the table (i.e., no other main effects or interactions were significant for any measure).