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# In Search of Integrative Processes: Basic Psychological Need Satisfaction Predicts Medial Prefrontal Activation During Decisional Conflict

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# In Search of Integrative Processes: Basic Psychological Need Satisfaction Predicts Medial Prefrontal Activation During Decisional Conflict

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Research has shown that people's abilities to develop and act from a coherent sense of self are facilitated by satisfaction of the basic psychological needs for competence, relatedness, and autonomy. The present study utilized functional near infrared spectroscopy (fNIRS) to examine the effect of need satisfaction on activity in the medial prefrontal cortex (MPFC), a key region in processing information about the self. Participants completed a decision-making task (e.g., Which occupation would you prefer, dancer or chemist?) in which they made a series of forced choices according to their personal preferences. The degree of decisional conflict (i.e., choice difficulty) between the available response options was manipulated on the basis of participants' unique preference ratings for the target stimuli, which were obtained prior to scanning. Need satisfaction predicted elevated MPFC activity during high-conflict relative to low-conflict situations, suggesting that one way need satisfaction may promote self-coherence is by enhancing the utilization of self-knowledge in the resolution of decisional conflicts.

*Keywords:* self-determination theory, basic psychological needs, self-referential processing, medial prefrontal cortex

In the classic psychodynamic and humanistic theories of personality, healthy development is characterized by the establishment of a coherent sense of self (e.g., Freud, 1923; Kohut, 1977; Rogers, 1951; Winnicott, 1965). Drawing on these traditions, self-determination theory (SDT; Deci & Ryan, 1985; Ryan & Deci, 2008) posits that people are naturally inclined to resolve psychological inconsistencies and conflicts and to synthesize and structure their ongoing experiences into a unified self. Within SDT, *integrative processes* refer to the supposed underlying mechanisms that enable people to develop and act from a coherent self. Integrative processes have traditionally been examined at the level of subjective experience, as specific experiential phenomena (e.g., identity consolidation in self-narratives; Weinstein, Deci, & Ryan, 2011) are seen as expressions of personality integration (Ryan, 1995; see Table 1). SDT also suggests, however, that for integrative processes to function effectively, three basic psychological needs must be satisfied. *Competence* refers to feelings of effectance, the sense of mastery in one's interactions with one's environment. *Relatedness* refers to feelings of social connectedness, the sense of being accepted and attuned with others. *Autonomy* refers to feelings of freedom and volition, the sense that one's behavior is internally initiated rather than externally coerced. Over the past 3 decades, research conducted across a variety of cultural contexts, developmental epochs, and life domains has consistently found that the experiences of competence, relatedness, and autonomy are associated with the development and sustained expression of integrative processes (Chirkov, Ryan, & Sheldon, 2011; Deci & Ryan, 2002). When people have their basic psychological needs satisfied, they accordingly evidence a variety of positive outcomes such as greater persistence and performance in their goal pursuits, improved affective experience, more fulfilling relationships, and overall psychological health (Chirkov et al., 2011; Deci & Ryan, 2002).

Despite decades of work examining the experiential and behavioral outcomes of need satisfaction, research has only begun to explore how the integrative tendency to develop and act in a self-coherent manner is constituted in the brain. In one recent investigation, Murayama, Matsumoto, Izuma, and Matsumoto (2010) used functional magnetic resonance imaging (fMRI) to explore the neural correlates of the undermining effect of monetary rewards on intrinsic motivation. The results of their study implicated the corticobasal ganglia network in the subjective experience and in the enactment of intrinsically motivated behavior. In another fMRI study, Lee and Reeve (2012) found that the imagined

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The optical brain imaging instrumentation utilized in the present research was manufactured by fNIR Devices, LLC. Hasan Ayaz was involved in the development of the technology and thus offered a minor share in fNIR Devices, LLC.

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Table 1
*An Incomplete List of Research Topics Within SDT That Are Conceptualized in Terms of Integrative Processes*

| Research topic | Brief description of the phenomenon as an expression of integrative processes | Important references |
|---|---|---|
| Intrinsic motivation | One's activities are spontaneously enacted out of personal interest. | Deci, Koestner, & Ryan (1999) |
| Internalization | One's sociocultural practices are brought into line with one's abiding goals and values. | Ryan & Connell (1989) |
| Intrinsic goal strivings | One's goal pursuits afford direct satisfaction of basic psychological needs. | Kasser & Ryan (1993, 1996) |
| Mindfulness | One's behavior is informed by a reflective awareness of one's emotions and impulses. | Brown, Ryan, & Creswell (2007) |
| Identity integration | One's identity is nondefensively explored; one's past self is seen as being connected and relevant to the current self. | Weinstein et al. (2011) |

*Note.* Within SDT, specific motivational phenomena represent different aspects of an overarching tendency to differentiate and consolidate one's regulatory processes and experiences into a unified sense of self. SDT = self-determination theory.

performance of self-determined, intrinsically motivated behaviors was associated with greater activation in the anterior insular cortex, a region previously associated with agentic, self-generated behavior. These researchers also showed that the imagined enactment of non-self-determined, extrinsically motivated behavior was associated with heightened activity in the angular gyrus, which has been previously associated with a loss of personal agency. Importantly, this burgeoning area of research has yet to directly examine how individual differences in need satisfaction bear upon integrative processes at the level of the brain.

A large body of neuroimaging work, however, suggests another approach to investigate the role of need satisfaction in the facilitation of self-coherence. The medial prefrontal cortex (MPFC) is preferentially activated in tasks that entail *self-referential processing*, such as reflecting upon one's own personality traits, feelings, and physical attributes (e.g., Jenkins & Mitchell, 2011) or reporting one's attitudes and preferences (for reviews, see Mitchell, 2009; Northoff & Bermpohl, 2004). Indeed, the effect of self-referential processing on MPFC activity is robust at many levels of analysis, having been observed across cultures (e.g., Wang et al., 2011) and across different sensory modalities (e.g., Northoff et al., 2006). Self-referential processing is also thought to have important implications for personal decision making. Given that personal questions provide no external standards with which to regulate one's own behavior, the resolution of such decisional conflicts requires the use of self-relevant information and, thus, engagement of the MPFC (Nakao et al., 2009; Nakao, Osumi, et al., 2010).

This research on the MPFC, wherein activity represents a reliable "neural signature" of self-referential processing (cf. Ames, Jenkins, Banaji, & Mitchell, 2008; Mitchell, Schirmer, Ames, & Gilbert, 2011), provides a starting point for specifying and investigating the nature of integrative processes at the level of the brain. A crucial aspect of personality integration is the extent to which one's behavior is guided by one's abiding preferences, goals, and values (Deci & Ryan, 2000; Ryan, 1995). Given the role of the MPFC in self-referential processing, we propose that the selective recruitment of self-knowledge mediated by the MPFC may be part of a functional network that constitutes the operation of what, at a more abstract or molar level of analysis, are referred to as integrative processes within SDT. More concretely, if basic psychological need satisfaction facilitates people's natural progression toward self-coherent behavior, then people who report more need satisfaction ought to show increased MPFC activation in experimental conditions that require the effective utilization of self-relevant information. Accordingly, forced-choice decision-making paradigms that require participants to utilize self-relevant information provide a methodological avenue to examine integrative processes at the level of the brain. Such experimental contexts preclude the possibility for one to regulate one's behavior according to externally specifiable "right" or "wrong" answers and instead challenge one to make decisions on the basis of self-relevant criteria (i.e., personal preferences).

In a set of fMRI studies, Nakao and colleagues used a personal choice paradigm to examine the role of the anterior cingulate cortex (ACC) and the MPFC in the selection of behavior without an objectively correct answer (Nakao et al., 2009; Nakao, Osumi, et al., 2010). Seven to 10 days before neuroimaging, participants completed a survey that asked them to rate how well they believed that they could perform a number of specific occupations (e.g., musician, dentist, comedian). Participants' ratings were used to create idiographically tailored occupational choice tasks that featured a high- and a low-conflict condition. In both conditions, two occupational words were presented side-by-side, and participants were asked to select the occupation that they believed they could perform better. The word pairs in the high-conflict condition consisted of similarly rated occupational words, whereas those in the low-conflict condition consisted of occupational words with greater differences in rating between them. Alongside this occupational choice task, participants also completed a control task in which they were told to simply select the longer word in each pair.

In keeping with the idea that self-knowledge represented in the MPFC is used to regulate decision making when external standards are not available, Nakao et al. (2009) found increased activation in MPFC in the occupational-choice task relative to the word-length task. Furthermore, they found increased dorsal ACC (dACC) activation during the high- relative to low-conflict conditions, a result that is consonant with other work suggesting that the dACC functions to evaluate the degree of conflict between competing response tendencies (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Nakao, Mitsumoto, et al., 2010). In follow-up research on these data using psychophysiological interaction analyses, Nakao, Osumi, et al. (2010) showed that correlations between dACC and MPFC activities were significantly greater in the occupational-choice task than in the word-length task. Taken together, these findings have been interpreted as suggesting a functional relation between the dACC and MPFC in decisional conflicts without recourse to any objectively specifiable standard. Specifically, Nakao, Osumi, et al. (2010) argued that decisional conflict is detected by the dACC and that the MPFC plays a role in subsequently reducing such conflict by biasing behavior selection through self-knowledge representation.

We adapted the occupational choice paradigm utilized by Nakao et al. (2009) to further examine the role of the MPFC in regulating decisional conflict and to test the idea that need satisfaction modulates MPFC activation in such contexts. Given that integrative processes are reflected in behavior that is based on one's personal goals and values, our occupational choice task required participants to choose which future career they would prefer from among pairs of target occupations. We adapted the occupational choice task previously utilized by Nakao and colleagues in this manner to make the experimental paradigm more conceptually relevant to the concept of integrative processes. On the basis of Nakao, Osumi, et al. (2010), we expected that MPFC activation would be greater in the high-relative to low-conflict conditions. We theorized that one way in which need satisfaction facilitates self-coherence is by improving the functional coordination between self-knowledge and choice behavior during decisional conflict. Specifically, we predicted that people who experience more need satisfaction in their day-to-day activities would be more likely to exhibit heightened MPFC activity during the regulation of decisional conflicts because previous research shows that need satisfaction facilitates the enactment of self-congruent behavior (Deci & Ryan, 1985, 1991, 2000; Ryan, 1995) and should accordingly promote the spontaneous recruitment self-relevant information to more effectively bias competing response tendencies in decisional contexts. Such an outcome would represent a neural indication that need satisfaction facilitates self-coherent behavior.

To measure MPFC activity, we utilized functional near infrared spectroscopy (fNIRS; for an overview, see Irani, Platek, Bunce, Ruocco, & Chute, 2007), an optical brain imaging technique that uses infrared light, introduced at the scalp, to continuously monitor relative changes in cerebral blood flow (see Irani et al., 2007). The fNIRS system utilized in the present study was originally designed by Britton Chance at the University of Pennsylvania and further developed at the Drexel University School of Biomedical Engineering, Science, and Health Systems. In the present study, we investigated relative changes in oxygenated hemoglobin (oxy-Hb; i.e., the evoked hemodynamic response) in the MPFC during the occupational choice task. The 16-channel fNIRS probe was fastened to participants' foreheads over standard electroencephalography positions $F_7$, $F_{P1}$, $F_{P2}$, and $F_8$ (see Figure 1). These channels provide coverage over the anterior portions of the frontal lobe and correspond to Brodmann areas 9, 10, 45, and 46.

In accordance with previous research using the same fNIRS system (e.g., Ayaz et al., 2006; Ayaz et al., 2012; Ruocco, Medaglia, Ayaz, & Chute, 2010), we assessed activity in the left- and right-MPFC with Channels 8 and 10, respectively. Although these channels collectively comprised our a priori region-of-interest (ROI), we examined each separately to test for the possibility of a lateralized effect. Ryan, Kuhl, and Deci (1997) broadly speculated that the right prefrontal cortex might be particularly important for generating holistic self-representations and thus might play a particularly important role in the instantiation of self-coherent behavior. Importantly, these speculations have not yet been empirically examined. Although Ryan et al.

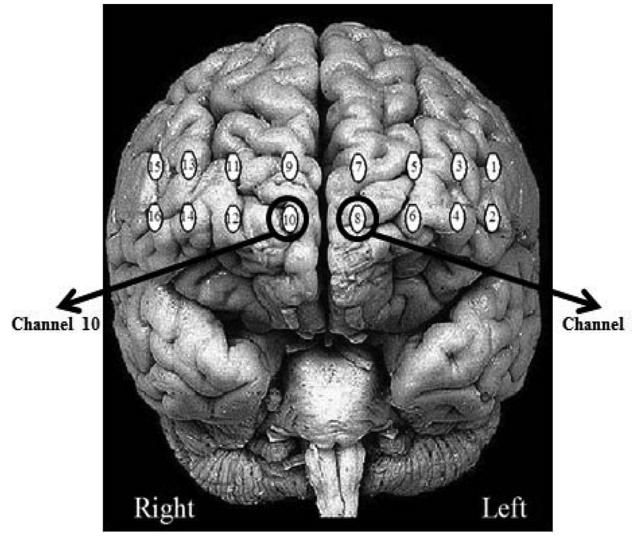


*Figure 1.* The 16 measurement locations (channels) of the fNIRS sensor pad. Channels 8 and 10 defined the MPFC, our a priori ROI. The brain surface image is from the University of Washington, Digital Anatomist Project (Ayaz et al., 2012). MPFC = medial prefrontal cortex; fNIRS = functional near infrared spectroscopy; ROI = region of interest.

(1997) did not specifically implicate the MPFC, the present research affords the opportunity for a preliminary test of these ideas.

# Method

## Participants

Sixty-seven students from the University of Toronto participated in this study, either for course credit in their introductory psychology course or for monetary compensation at a rate of $15 CAN ($15.40 U.S.) per hour. The study consisted of two 1.5 hr laboratory sessions spaced 7 to 10 days apart. In the first session, participants completed a number of questionnaires (see Self-Report Measures). In the second session, participants completed the occupational choice task during fNIRS. Two participants were excluded from the analyses because they were age outliers (36 and 44 years old), and one participant was excluded because of procedural noncompliance. The remaining 64 participants ranged in age from 18 to 26 ($M$ = 21.53, $SD$ = 1.78). The sample was ethnically diverse, mostly consisting of students from South Asian (47%) and East Asian (22%) backgrounds. A smaller proportion described themselves as White (9%) and the remainder came from a broad range of ethnicities (22%).

## Self-Report Measures

**Occupational survey.** Participants were presented with a list of 107 occupational words (e.g., teacher, writer, politician) and were asked to indicate the extent to which they believed that they might experience personal satisfaction and enjoyment in each occupation as a possible future career. The items on this occupational survey were based on those utilized by Nakao et al. (2009). Participants were instructed to use their personal preferences as a guide while they rated the items on a 4-point scale ranging from 1 (*no satisfaction and enjoyment*) to 4 (*a lot of satisfaction and enjoyment*).

**Need satisfaction.** To measure the extent to which participants experience competence, relatedness, and autonomy in their day-to-day activities, participants completed an 18-item basic need satisfaction scale (Sheldon & Gunz, 2009; Sheldon & Schuler, 2011) that asked them to indicate the extent to which a number of statements described their feelings during the last week on a scale ranging from 1 (*not at all true*) to 7 (*very true*). This scale contained six items each for competence, relatedness, and autonomy. Sample items are as follows: "I successfully completed difficult tasks and projects" (competence); "I felt close and connected with people who are important to me" (relatedness); and "I was free to do things my own way" (autonomy). Because these items were utilized to index participants' global level of need satisfaction, a composite measure was formed by aggregating the items from the three subscales ($M = 4.54$, $SD = 0.84$, $\alpha = .76$). This global assessment strategy is commonly utilized in SDT research (e.g., Deci et al., 2001; Weinstein & Ryan, 2010) and is based on SDT's view of competence, relatedness, and autonomy as complementary facilitators of integrative processes (see Deci & Ryan, 2000; Ryan, 1995). In keeping with previous SDT research, participants' experiences of competence, relatedness, and autonomy were interrelated: competence-relatedness ($r = .29$), $t(62) = 2.38$, $p < .05$; competence-autonomy ($r = .45$), $t(62) = 4.00$, $p < .001$; relatedness-autonomy ($r = .32$), $t(62) = 2.69$, $p < .01$.

## The Occupational Choice Task

To produce the stimuli for the high- and low-conflict conditions, we followed a set of procedures that was analogous to those described by Nakao et al. (2009). For each participant, we constructed a high-conflict/high-preference condition (hereafter HC-H) in which the nine occupational words that were rated most favorably were used as stimuli; a high-conflict/low-preference condition (hereafter HC-L) in which the nine occupational words that were rated least favorably were used as stimuli; and a low-conflict condition (hereafter LC) in which the word stimuli utilized in the HC-H and HC-L conditions were paired to produce clear differences in preference. To ensure adequate differences between the conditions, we required participants to provide at least seven high-preference occupational words with a maximally favorable rating of "4" and at least seven low-preference occupation-related words with a maximally unfavorable rating of "1." If needed, the remaining two high- and low-preference occupational words were drawn from those that the participant had respectively rated at "3" and "2" in terms of personal preference. When participants supplied multiple occupational words with the same rating, we selected the occupational words that had received the highest ratings from students in our piloting of the occupational survey ($N = 110$). Through this labor-intensive procedure, we idiographically manipulated the pairing of word stimuli for each participant.

The trials for the HC-H and the HC-L conditions were constructed by forming all possible combinations of word-pairs among the 9 high- and 9 low-preference occupational words, respectively. This resulted in a total of 36 trials for each of these high-conflict conditions. The trials for the LC condition were constructed by joining each of the 9 high-preference words with each of the 9 low-preference words. This resulted in a total of 81 trials within the LC condition. Altogether, this method for constructing trails yielded a total of 153 trials for each participant (i.e., 36 HC-H trials + 36 HC-L trials + 81 LC trials).

There were two minor differences between the Nakao et al. (2009) paradigm and the one described here. First, whereas the occupational choice task used by Nakao et al. (2009) consisted of 6 blocks (3 for each of the high- and low-conflict conditions), our occupational choice task consisted of 9 blocks, with 3 blocks for each of the HC-H, HC-L, and LC conditions. Second, whereas each block in Nakao et al.'s (2009) occupational choice task contained 9 trials, our occupational choice task contained 12 trails per block in both the HC-H and HC-L conditions and 27 trials per block in the LC condition. Following Nakao et al. (2009), the order of blocks during the occupational choice task was pseudorandomized with the stipulation that the same condition could not be presented twice in a row.

Figure 2 exemplifies the flow of one trial in the occupational choice paradigm. Trials for both the HC-H and HC-L conditions were formed by pairing each of the 9 occupational words with the 8 other occupational words from the respective condition. In both the HC-H and HC-L conditions, each stimulus word thus appeared a total of 8 times. On 4 trials, each occupational word appeared on the right-hand side of the screen. On the other 4 trials, each occupational word appeared on the left-hand side of the screen. Within each of the HC-H and HC-L blocks, trials were ordered randomly with the qualification that each occupational word was never presented on consecutive trials. Between each of the HC-H and HC-L blocks, trials featuring the occupational words were distributed as evenly as possible across the three blocks (i.e., 3 times in the first HC-H block, 2 times in the second HC-H block, and 3 times in the third HC-H block). Trials for the LC condition were formed by pairing each of the 9 high-preference words with each of the 9 low-preference words. In the LC condition, each stimulus word thus appeared a total of 9 times. Given this odd number of presentations, for each participant, we randomly selected 5 high-preference occupational choice words to appear with 5 low-preference occupational choice words on the right-hand side

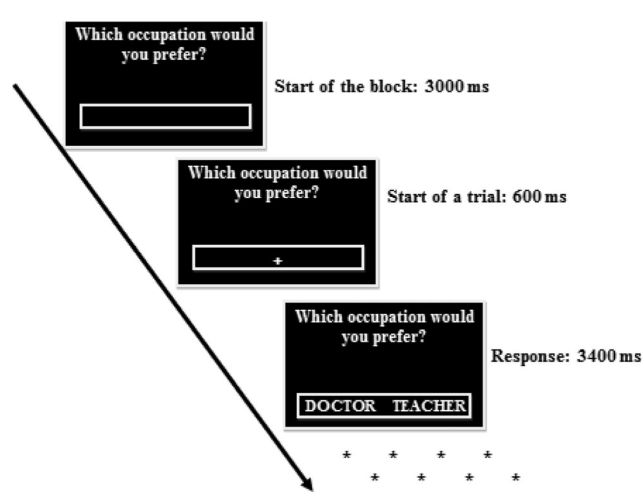


*Figure 2.* Exemplary flow of one trial (4,000 ms total) in the occupational choice paradigm. The entire task consisted of 153 trials, which were divided into nine blocks and presented in a pseudorandomized manner.

of the screen 5 times. Within each of the LC blocks, trials were ordered randomly with the qualification that each occupational word was never presented on consecutive trials. Within the LC condition, trials featuring the same occupational words were distributed as evenly as possible across the three LC blocks (i.e., 3 times in the first LC block, 3 times in the second LC block, and 3 times in the third LC block).

## The Neuroimaging Protocol

Participants were seated in a dark room in front of a computer monitor. After the fNIRS probe was secured on the participants' foreheads, participants were asked to directly stare at a crosshair fixation for 10 s to establish baseline fNIRS parameters. Participants were first given 24 practice trials to familiarize them with the task. The word stimuli consigned to the practice trials were those that participants had previously given "medium" preference ratings. These items were not utilized in the actual experiment.

As shown in Figure 2, the experiment began with the appearance of the question, "Which occupation would you prefer?" on the screen for 3 s. This question was presented in white color against a black background. Beneath this question, there appeared a white rectangle, within which the stimulus words would appear. Each trial began with a 600 ms presentation of this same display, except with a crosshair fixation in the middle of the rectangle. Then, for 3,400 ms, two stimulus words appeared on the screen within the rectangle. Participants were told that there was no objectively correct answer to each question and that they should make their choices by using their own personal preferences as a guide. Participants were also instructed to respond as quickly as possible on each trial by pressing one of two keyboard buttons using the corresponding index finger or the middle finger of their right hand. After the 3,400 ms elapsed, the next trial began. Participants' reaction times (RTs) were defined as the time elapsed from the onset of each trial to the registration of participants' corresponding button press.

## Data Requirements

Of the 64 individuals who completed the study, 37 provided maximally favorable ratings of "4" for least 7 word items on the occupational survey; all 64 participants provided maximally unfavorable ratings of "1" for at least 7 word items on the occupational survey. With regard to the 27 participants who did not provide at least 7 maximally favorable ratings, we excluded their fNIRS and behavioral data for the HC-H and LC conditions in the analyses. We nonetheless included their fNIRS and behavioral data from the HC-L condition in the analyses as the constituent occupational word stimuli met the previously described data requirements.

**Behavioral data.** The aforementioned data requirements yielded a total of 6,633 decisional trials that were executed from the 64 participants who completed the study. Among these data points, RTs for 52 trials were not recorded because participants did not execute the instructed behavioral responses on these trials. In total, 6,581 data points from 64 participants were included in the behavioral analyses.

**fNIRS data.** The aforementioned data requirements yielded a total of 411 blocks of fNIRS data from the 64 participants who completed the study. The brain imaging data from one participant was not analyzable because of a procedural omission in setting up the fNIRS probe. For each of the other 63 participants, raw fNIRS data were visually inspected, and readily visible saturated channels were excluded. Then, a sliding window motion artifact rejection algorithm was applied, and the data were low-pass filtered with a finite impulse response and linear phase filter with order 20 and a cut-off frequency of 0.1 Hz to attenuate the high frequency noise, respiration, and cardiac cycle effects (Ayaz, Izzetoglu, Shewokis, & Onaral, 2010; Ayaz et al., 2012; Ayaz et al., 2011; Izzetoglu et al., 2005). For the left-MPFC, a total of 88 out of original 567 blocks were rejected (28 for the HC-H condition, 31 for the HC-L condition, and 29 for the LC condition). For the right-MPFC, a total of 87 out of original 567 blocks were rejected (26 for the HC-H condition, 33 for the HC-L condition, and 28 for the LC condition).

Alongside the previously described data requirements in constructing the occupational choice task, the data exclusions detailed above yielded a total of 337 blocks from 56 individuals that were submitted for analyses for the left-MPFC and a total of 335 blocks from 56 individuals that were submitted for analysis for the right-MPFC. For each of the 9 blocks in this study, changes in oxy-Hb in the left- and right-MPFC were calculated relative to the beginning of the task period when the baseline fNIRS parameters were established.

# Results

The data were analyzed with multilevel models (Bryk & Raudenbush, 1992; Kenny, Kashy, & Bolger, 1998). Within the context of the present study, multilevel models take into account that the experimental trials and blocks are nested within participants and that the data are unbalanced across participants. Variance in the dependent variable is partitioned into within-person (Level 1) and between-person (Level 2) components, allowing predictor terms to be represented at both the level of the experimental trial or block (Level 1) and at the level of the participant (Level 2). We examined the Level 1 effect of decisional conflict, the Level 2 effect of need satisfaction, and the Decisional Conflict × Need Satisfaction cross-level interaction on participants' RTs and relative oxy-Hb in the left- and right-MPFC during the occupational choice task. The multilevel models were estimated in R (R Development Core Team, 2010) using the multilevel and nlme packages (Bliese, 2009). We estimated random intercept models, nesting the 153 individual RTs and nine experimental blocks of fNIRS data within each participant.[1]

In the primary analyses, decisional conflict was treated as a class variable with three levels (LC, HC-H, HC-L) and need satisfaction scores were centered. Following the recommendations of West, Aiken, and Krull (1996), we performed two orthogonal contrasts in our primary analyses to test our a priori hypotheses. Of principle interest was the first contrast (C1), which compared RTs and relative oxy-Hb levels in the LC condition with the HC-H and HC-L conditions. For C1, the LC, HC-H, and HC-L conditions

[1] For the RT data, the intraclass correlation coefficient was significant ($\rho = 0.39$), $t(6698) = 34.66$, $p < .001$, suggesting that the participants' RTs for each trial were not independent and confirming that a multilevel analysis is necessary for these data. For the fNIRS data, however, the intraclass correlation coefficients for both the left- MPFC and right-MPFC were very close to zero and not significant. Nevertheless, given the nested structure of these data, all analyses were conducted using multilevel models.

were coded as −2/3, 1/3, and 1/3, respectively. Thus, a one-unit change on C1 represents the mean difference between the high- and low-conflict conditions. The second contrast (C2) was exploratory and compared RTs and oxy-Hb levels in the HC-H and HC-L conditions.[2] For C2, the LC, HC-H, and HC-L conditions were coded as 0, −1/2, and 1/2, respectively. Thus, a one-unit change on C2 represents the mean differences between the HC-H and HC-L conditions. Most importantly, the C1 × Need Satisfaction interaction term examined the extent to which a one-unit difference between the high- and low-conflict conditions was influenced by participants' levels of need satisfaction. The C2 × Need Satisfaction interaction term examined the extent to which a one-unit difference between the HC-H and HC-L conditions was influenced by participants' levels of need satisfaction. Table 2 displays the full results of these primary multilevel analyses.

## Behavioral Analyses

The results of the behavioral analyses are displayed in Model 1 of Table 2. We calculated the proportional reduction in prediction error for each level of our primary models according to the recommendations of Snijders and Bosker (1994, 1999). Model 1 reduced prediction error of RT by a moderate amount both at the level of the trial (Level 1), $R^2_{\text{Level 1}} = .16$, and at the level of the participant (Level 2), $R^2_{\text{Level 2}} = .15$. Consistent with earlier research (Nakao et al., 2009) and indicative of a successful manipulation, the C1 contrast term revealed that participants had longer RTs in the high- relative to low-conflict conditions, on average taking 370.74 ms longer to respond to individual trials in the high-conflict conditions. Interestingly, the C2 contrast term revealed that participants had a more difficult time choosing between two low-preference items as opposed to two high-preference items, on average taking 161.96 ms longer to respond to individual trials in the HC-L condition relative to the HC-H condition. Although the main effect for need satisfaction on RT was not significant, the C1 × Need Satisfaction interaction term revealed that need satisfaction significantly moderated the effect of decisional conflict (low-relative to high-conflict) on individuals' RT. Need satisfaction did not significantly moderate the effect of decisional conflict between the two high-conflict conditions.

To begin our examination of the significant C1 × Need Satisfaction interaction term, we plotted and examined the simple slopes of the C1 contrast term at high (+1 SD) and low (−1 SD) levels of need satisfaction (Aiken & West, 1991). The significant interaction is illustrated in Figure 3A. The simple effect of decisional conflict was more pronounced among participants reporting higher levels of need satisfaction (+1 *SD*), $b = 406.67$, $SE = 14.99$, $t(6513) = 27.12$, $p < .0001$, than among participants reporting lower levels of need satisfaction (-1 *SD*), $b = 331.82$, $SE = 14.74$, $t(6513) = 22.51$, $p < .0001$. These unstandardized regression coefficients signify that participants reporting higher levels of need satisfaction on average took 406.67 ms longer to respond to individual trials in the HC-H and HC-L conditions relative to the LC condition, but that those participants reporting lower levels of need satisfaction on average only took 331.82 ms longer to respond to individual trials in the HC-H and HC-L conditions relative to the LC condition.

To further investigate the significant C1 × Need Satisfaction interaction term, we examined the simple slopes of need satisfaction at low- and high-levels of decisional conflict. The simple effect of need satisfaction was not significant in either the LC condition, $b = 18.10$, $SE = 49.24$, $t(62) = .37$, $p = .71$, or in the HC conditions, $b = 62.65$, $SE = 48.74$, $t(62) = 1.29$, $p = .20$. These unstandardized regression coefficients signify that although need satisfaction on average predicted slightly longer RTs within both low- and high-conflict conditions (about 18.10 ms and 62.65 ms, respectively), these longer reaction times were not significantly different from zero.

## fNIRS Analyses

We first examined whether RT predicted oxy-Hb in the left- and right MPFC. For these analyses, participants' RTs were averaged within each experimental block and person-mean centered. Results indicated that RT was a significant predictor of oxy-Hb levels in the left-MPFC, $b = 0.0003$, $SE = .0001$, $t(280) = 2.75$, $p < .01$, and a marginally significant predictor of oxy-Hb levels in the right-MPFC, $b = 0.0002$, $SE = .0001$, $t(278) = 1.88$, $p < .10$. These results suggest that longer RTs were positively associated with activation in both the left- and right-MPFC throughout the occupational choice task. We accordingly included participants' person-mean centered RTs as a covariate in all subsequent models to control for possible behavioral confounds.

The results of the fNIRS analyses are displayed in Models 2 and 3 of Table 2. Once again, we calculated the proportional reduction in prediction error for each level of our models according to the recommendations of Snijders and Bosker (1994, 1999). Model 2 reduced prediction error of relative oxy-Hb levels by a small amount both at the level of the block (Level 1), $R^2_{\text{Level 1}} = .04$, and at the level of the participant (Level 2), $R^2_{\text{Level 2}} = .04$. Model 3 similarly reduced prediction error of relative oxy-Hb levels by a small amount both at the level of the block (Level 1), $R^2_{\text{Level 1}} = .03$, and at the level of the participant (Level 2), $R^2_{\text{Level 2}} = .03$.

On the basis of previous research (Nakao et al., 2009; Nakao, Osumi, et al., 2010), we expected greater MPFC activity in the high- relative to low-conflict conditions. As further evidence of a successful manipulation, the C1 contrast term was significant in both the left- and right-MPFC. The C2 contrast term was only marginally significant in the left-MPFC and not significant in the right-MPFC. Because we did not have strong hypotheses about the C2 contrast term and included it for purely exploratory reasons, we cease all further discussion of it. In keeping with Ryan et al. (1997), the C1 × Need Satisfaction interaction term was not significant in the left-MPFC, but it was significant in the right-MPFC.

[2] Decisional conflict arises when incompatible response tendencies are simultaneously active, and the amount of conflict is believed to be greatest when the strength of the competing responses is equal (Botvinick et al., 2001). In the context of the forced-choice paradigm of the present investigation, there is no strong theoretical rationale to suspect that the amount of decisional conflict would differ between the HC-H and HC-L conditions, as participants' absolute preference levels for each of the occupational words within either the HC-H and HC-L conditions are more or less equal (Nakao, Mitsumoto, et al., 2010; Nakao et al., 2009; Nakao, Osumi, et al., 2010). Our subjective reflections upon the nature of the HC-H and HC-L trials, however, lead us to intuitively suspect that the amount of decisional conflict may differ between these conditions. We examined this possibility here for strictly exploratory purposes.

Table 2
*Multilevel Analyses of the Effect of Decisional Conflict on Reaction Time and MPFC Activity (Oxy-Hb Changes) as Moderated by Need Satisfaction*

| Model | *b* | *SE* | *df* | *t* | *p* |
|---|---|---|---|---|---|
| Model 1: RT | | | | | |
| C1 | 370.74 | 10.58 | 6513 | 35.04 | .0000 |
| C2 | 161.96 | 15.39 | 6513 | 10.52 | .0000 |
| Need Satisfaction | 45.38 | 48.39 | 62 | 0.94 | .3520 |
| C1 × Need Satisfaction | 43.78 | 12.24 | 6513 | 3.58 | .0003 |
| C2 × Need Satisfaction | −7.41 | 17.85 | 6513 | −0.42 | .6780 |
| Model 2: Δ oxy-Hb (μmolar) in the left-MPFC | | | | | |
| C1 | 0.15 | 0.07 | 276 | 2.16 | .0318 |
| C2 | 0.12 | 0.06 | 276 | 2.00 | .0468 |
| Need Satisfaction | 0.01 | 0.03 | 54 | 0.45 | .6509 |
| C1 × Need Satisfaction | 0.09 | 0.07 | 276 | 1.28 | .2004 |
| C2 × Need Satisfaction | −0.01 | 0.08 | 276 | −0.20 | .8440 |
| Model 3: Δ oxy-Hb (μmolar) in the right-MPFC | | | | | |
| C1 | 0.18 | 0.07 | 274 | 2.62 | .0093 |
| C2 | 0.05 | 0.06 | 274 | 0.90 | .3686 |
| Need Satisfaction | 0.01 | 0.03 | 54 | 0.32 | .7469 |
| C1 × Need Satisfaction | 0.14 | 0.06 | 274 | 2.25 | .0254 |
| C2 × Need Satisfaction | −0.01 | 0.06 | 274 | −0.10 | .9230 |

*Note.* All models were estimated using an unstructured covariance matrix and the between–within method of estimating degrees of freedom. C1 compared the unweighted means of the low-conflict condition and the two high-conflict conditions. C2 compared the unweighted means of the two high-conflict conditions. Model 1 was estimated with 6,581 data points from 64 individuals. Model 2 was estimated with 337 data points from 56 individuals. Model 3 was estimated with 335 data points from 56 individuals. In Models 2 and 3, participants' person-mean centered RTs were entered as a covariate, the effects of which were not significant in either model. MPFC = medial prefrontal cortex; RT = reaction time; oxy-Hb = oxygenated hemoglobin; C = contrast.

The significant interaction is illustrated in Figure 3B. In keeping with our prediction, the simple effect of decisional conflict was more pronounced and significantly different than zero among participants reporting higher levels of need satisfaction (+1 *SD*), $b = 0.29$, $SE = .09$, $t(274) = 3.39$, $p < .001$, relative to those participants reporting lower levels of need satisfaction (−1 *SD*), for which the simple effect was not significantly different than zero, $b = 0.07$, $SE = .08$, $t(274) = .79$, $p = .43$. These unstandardized regression coefficients signify that, in the right-MPFC, high- relative to low-decisional conflict predicted a .29 μmolar increase of oxy-Hb levels among those participants reporting higher levels of need satisfaction; among those participants who reported lower levels of need satisfaction, decisional conflict did not predict any significant changes in oxy-Hb levels.

To further investigate the significant C1 × Need Satisfaction interaction term in the right-MPFC, we examined the simple slopes of need satisfaction at low- and high-levels of decisional conflict. The simple effect of need satisfaction was marginally significant in the HC conditions, $b = 0.05$, $SE = .03$, $t(54) = 1.72$, $p < .10$, but was not significant in the LC condition, $b = -0.08$, $SE = .05$, $t(54) = -1.59$, $p = .12$. These unstandardized regression coefficients signify that need satisfaction predicted higher levels of oxy-Hb in the right-MPFC in the HC conditions and tended to be associated with lower levels of oxy-Hb in the right-MPFC in the LC condition, although this latter effect was not significant.

In sum, people who reported higher levels of need satisfaction evidenced greater MPFC activity in the high- relative to low-conflict conditions. While the Decisional Conflict × Need Satisfaction interaction on MPFC activity was paralleled by longer response latencies in the high- relative to low-conflict conditions, we feel confident stating that the effect on MPFC activity was neither due to nor driven by these behavioral effects given that we included participants' response latencies as a covariate in all fNIRS analyses.

The skeptical reader may be wondering whether the present findings were obtained because those participants who reported the lowest levels of need satisfaction were also those participants who were the least engaged by the task. However, if need satisfaction were simply a proxy for levels of task engagement, then we would expect participants with lower levels of need satisfaction to invest less effort in all three experimental conditions; in essence, we would expect a significant main effect for need satisfaction in addition to the interactions that we predicted. Given that the main effect for need satisfaction was not significant for either response latency or MPFC activity, we think it unlikely that the presently obtained interactions were artifactually driven by differences in participants' levels of task engagement.

## Ancillary Analyses

We ran an additional multilevel model to examine the relative contribution of each psychological need in the Decisional Conflict × Need Satisfaction effect observed in the right-MPFC. Model 4 accordingly featured a main effect term for decisional conflict (low-conflict = −1, high-conflict = 1), a main effect term for each psychological need, and three categorical by continuous variable interaction terms for each psychological need. The results of this analysis are featured in Table 3. Although the main effect for decisional conflict was significant, the main effect and interaction terms for each psychological need were not significant. Because regression coefficients represent the unique effect of each independent variable, this analysis suggests that the interaction effect observed in Model 3 was driven by the variance that is common across need satisfaction indices. These results are in

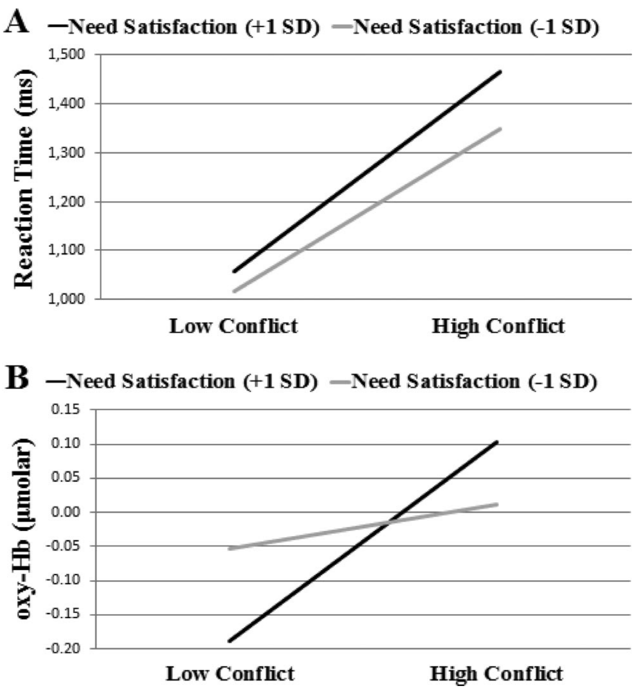


*Figure 3.* A: Predicted reaction time across levels of decisional conflict and need satisfaction. B: Predicted oxy-Hb response in the right-MPFC across levels of decisional conflict and need satisfaction. MPFC = medial prefrontal cortex; oxy-Hb = oxygenated hemoglobin.

correspondence with SDT's perspective that each need is important in the promotion of integrative processes.

Given that a large proportion of participants came from Asian backgrounds, reviewers invited us to explore whether culture held any relationship with need satisfaction or with right-MPFC activity in the regulation of decisional conflict. We accordingly conducted ancillary analyses in which culture was effect-coded (Other = −1, Asian = 1). Correlational analyses revealed that culture was not related to participants' levels of need satisfaction ($r$ = .05), $t(62) = 0.37$, $p = .71$. We also estimated a multilevel model to examine whether culture moderated the effect of either decisional conflict or the Decisional Conflict × Need Satisfaction interaction effect observed in the right-MPFC. The Decisional Conflict × Culture interaction term in Model 5 formally compared the effect of decisional conflict among the participants of Asian descent with all other participants in our sample. The Decisional Conflict × Culture × Need Satisfaction three-way interaction term similarly compared the magnitude of the Decisional Conflict × Need Satisfaction interaction among the participants of Asian descent with all other participants in our sample. Although the results of Model 5 once again found support for the hypothesized Decisional Conflict × Need Satisfaction interaction, culture moderated neither the effect of decisional conflict nor the Decisional Conflict × Need Satisfaction interaction. These results suggest that the interaction observed in Model 3 was not artifactually driven by Asian participants experiencing lower (or higher) levels of need satisfaction and, simultaneously, lower (or higher) levels of MPFC engagement (i.e., less self-knowledge biasing) during the resolution of decisional conflicts.

We also ran a multilevel model to formally compare activation in the left- and right-MPFC. In Model 6, decisional conflict was once again effect-coded (low-conflict = −1, high-conflict = 1), and participants' need satisfaction scores were mean-centered. Importantly, Model 6 also featured a term for fNIRS Channel, which compared activation in the left- and right-MPFC (left-MPFC = −1, right-MPFC = 1), along with all possible interaction terms. The formal test of a laterality effect was provided by the Decisional Conflict × fNIRS Channel × Need Satisfaction three-way interaction term, which compared the magnitude of the Decisional Conflict × Need Satisfaction interaction in the left- and right-MPFC. The results of Model 6 once again found support for the prediction that need satisfaction moderated MPFC activation across levels of decisional conflict, as the Decisional Conflict × Need Satisfaction interaction was significant. However, the results of Model 6 suggest that this two-way interaction did not significantly differ in the left- and right-MPFC, as the Decisional Conflict × fNIRS Channel × Need Satisfaction interaction term was not significant. This finding suggests that while the Decisional Conflict × Need Satisfaction interaction term was significantly different from zero in the right-MPFC, it did not significantly differ from the Decisional Conflict × Need Satisfaction interaction term in the left-MPFC (which was itself not significantly different from zero). Future research will thus be needed to more fully examine the extent of a laterality effect.

## Discussion

Basic psychological needs define the experiences that facilitate people's natural tendencies to develop and act from a cohesive sense of self (Deci & Ryan, 1985, 1991, 2000; Ryan, 1995). Our results show that need satisfaction influences the way in which people regulate decisional conflict, providing a new type of empirical support for SDT's proposal of integrative processes. Specifically, we found that people who report greater need satisfaction exhibit preferential engagement of the MPFC when competing personal response tendencies are simultaneously activated. Within the context of previous neuroimaging studies (e.g., Nakao et al., 2009; Nakao, Osumi, et al., 2010), these results suggest that people with higher levels of need satisfaction spontaneously recruit self-representations to bias their behavioral selections when resolving decisional conflicts. Within the context of SDT, these results suggest that need satisfaction improves the functional coordination between self-knowledge and choice behavior during decisional conflict and, in so doing, provides further evidence of need satisfaction in the facilitation of self-coherent behavior. Importantly, this pattern of MPFC activity within people reporting higher levels of need satisfaction was accompanied with more pronounced differences in RT across levels of decisional conflict, with longer response latencies in the high- relative to low-conflict conditions. All together, these results suggest that need satisfaction promotes self-regulatory capacities to flexibly and adaptively respond to situational challenges (cf. Block & Block, 1980).

The present study benefited from adapting an existing decision-making paradigm that previously established the role of the MPFC in the regulation of decisional conflict (Nakao et al., 2009; Nakao, Osumi, et al., 2010). Indeed, the present study demonstrated the generality of those previous findings by obtaining analogous results using fNIRS as a neuroimaging methodology. Although SDT

Table 3
*Ancillary Multilevel Analyses*

| Model | *b* | *SE* | *df* | *t* | *p* |
|---|---|---|---|---|---|
| Model 4: Δ oxy-Hb (μmolar) in right-MPFC | | | | | |
| Decisional Conflict | 0.09 | 0.03 | 274 | 2.50 | .0130 |
| Competence | 0.00 | 0.03 | 52 | 0.16 | .8755 |
| Relatedness | 0.01 | 0.03 | 52 | 0.27 | .7844 |
| Autonomy | −0.02 | 0.03 | 52 | −0.82 | .4187 |
| Decisional Conflict × Competence | 0.03 | 0.03 | 274 | 0.98 | .3264 |
| Decisional Conflict × Relatedness | 0.04 | 0.03 | 274 | 1.36 | .1735 |
| Decisional Conflict × Autonomy | 0.01 | 0.03 | 274 | 0.38 | .7017 |
| Model 5: Δ oxy-Hb (μmolar) in right-MPFC | | | | | |
| Decisional Conflict | 0.09 | 0.03 | 274 | 2.60 | .0098 |
| Culture | 0.02 | 0.03 | 52 | 0.75 | .4571 |
| Need Satisfaction | −0.02 | 0.03 | 52 | −0.55 | .5823 |
| Decisional Conflict × Culture | 0.01 | 0.03 | 274 | 0.21 | .8338 |
| Decisional Conflict × Need Satisfaction | 0.07 | 0.03 | 274 | 2.21 | .0282 |
| Culture × Need Satisfaction | −0.02 | 0.03 | 52 | −0.79 | .4311 |
| Decisional Conflict × Culture × Need Satisfaction | −0.02 | 0.03 | 274 | −0.60 | .5503 |
| Model 6: Δ oxy-Hb (μmolar) in MPFC | | | | | |
| Decisional Conflict | 0.08 | 0.02 | 605 | 3.35 | .0009 |
| fNIRS Channel | 0.00 | 0.02 | 605 | 0.06 | .9537 |
| Need Satisfaction | −0.01 | 0.02 | 58 | −0.30 | .7646 |
| Decisional Conflict × fNIRS Channel | 0.00 | 0.02 | 605 | −0.23 | .8217 |
| Decisional Conflict × Need Satisfaction | 0.06 | 0.02 | 605 | 2.43 | .0153 |
| fNIRS Channel × Need Satisfaction | −0.01 | 0.02 | 605 | −0.26 | .7988 |
| Decisional Conflict × fNIRS Channel × Need Satisfaction | 0.01 | 0.02 | 605 | 0.46 | .6438 |

*Note.* All models were estimated using an unstructured covariance matrix and the between–within method of estimating degrees of freedom. In all models, the Decisional Conflict term compared the unweighted means of the low-conflict condition and the two high-conflict conditions. In all models, participants' person-mean centered RTs were entered as a covariate, the effects of which were not significant in any model. In Model 4, participants' scores for Competence, Relatedness, and Autonomy were mean centered. In Model 5, the Culture term compared the unweighted mean of participants' of Asian descent with all other participants. Model 6 was estimated with 672 data points from 60 individuals. In Model 5, the Channel term compared the unweighted means of the left-MPFC and right-MPFC. MPFC = medial prefrontal cortex; oxy-Hb = oxygenated hemoglobin; RTs = reaction times; fNIRS = functional near infrared spectroscopy.

maintains that integrative processes and basic psychological needs represent universal features of personality development, it also highlights the possibility for cultural differences in the ways in which integrative processes are expressed (Deci & Ryan, 2000, 2008; Ryan & Deci, 2008). Indeed, a great deal of SDT research supports this position (e.g., see Chirkov et al., 2011). In this regard, it is interesting to note that the present investigation was similar to the previous research by Nakao and colleagues (Nakao et al., 2009; Nakao, Osumi, et al., 2010) in that it was conducted on a predominantly Asian sample. The current research, however, was not designed, and is therefore not well-suited, to examine whether there exist cross-cultural differences in how basic need satisfaction modulates the activity of the medial prefrontal cortex in the resolution of decisional conflict. Nevertheless, the results of our ancillary analyses indicate that culture moderated neither the effect of decisional conflict on MPFC activity nor the interaction between need satisfaction and decisional conflict on MPFC activity. Thus, with respect to the regulation of decisional conflicts, these findings provide preliminary evidence that the effect of need satisfaction on MPFC functioning generalizes across cultures. Future research would benefit by more thoroughly examining the possible moderating role of culture in the neurobiological underpinnings of integrative processes beyond the MPFC.

The results of the present research do raise a number of basic theoretical questions and issues. A principle concern for future research will be to more closely examine the mechanism (or mechanisms) for the present findings. For example, need satisfaction may influence MPFC activity during decisional conflict because greater need satisfaction renders individuals more conscious of decisional conflict in the first place. This would be consistent with previous SDT research showing that integrative tendencies entail reflective awareness and nondefensive reactions to psychological threat (e.g., Brown, Ryan, & Creswell, 2007). If this is the case, then activity in the dACC—given its purported role in the detection of decisional conflict (Botvinick et al., 2001; Nakao, Mitsumoto, et al., 2010; Nakao et al., 2009; Nakao, Osumi, et al., 2010)—may stand to mediate the simple effect of need satisfaction on MPFC activity in the high-conflict conditions of the present study. In this light, an important limitation of the present research is that our fNIRS system was only sensitive to hemodynamic changes within the top 2–3 mm of the cerebral cortex (see Irani et al., 2007); as a consequence, we cannot presently address this question.

Another (and nonmutually exclusive) possibility is that people with higher levels of need satisfaction are simply better able to access and utilize self-relevant information to appropriately bias response behavior once decisional conflict is detected by the dACC and the MPFC has been engaged. If this is the case, then the presently observed effect of need satisfaction on MPFC activity ought to generalize across diverse types of self-referential decision-making tasks (cf. Jenkins & Mitchell, 2011). Importantly, the current results are in line with Ryan et al.'s (1997) idea that the right prefrontal cortex plays a pronounced role in the regulation of self-coherent behavior. Although we are reluctant to further discuss the issue of lateralization at this point both because our formal analyses do not provide support for a laterality effect and because previous research has not localized self-referential processing in the right MPFC, future investigations should continue to explicitly test the possibility that distinct regions in the right prefrontal cortex are particularly important for self-coherent behavior.

Although the purpose of the present investigation was to investigate how need satisfaction modulates MPFC activity across levels of decisional conflict (i.e., low-conflict and high-conflict), it is also interesting to consider the present results in light of emerging research on the neural correlates of cognitive dissonance (e.g., Izuma et al., 2010; Jarcho, Berkman, & Lieberman, 2011; Qin et al., 2011). Indeed, the HC-H condition of the occupational choice task utilized in the present study is reminiscent of research in cognitive dissonance using decision-making paradigms in which participants are asked to make preference-based choices among a set of similarly valued objects (e.g., food items, CDs, etc.). Making such choices is believed to induce a state of psychological discomfort called "cognitive dissonance" as one's cognitions in favor of the rejected but nonetheless positively valued alternative are discordant with one's choice behavior. To alleviate this postdecisional dissonance, people sometimes increase their preference for the chosen object and decrease their preference for the rejected object, a phenomenon known as the "spreading of alternatives." In keeping with the MPFC's purported role in the regulation of decisional conflicts (Nakao et al., 2009; Nakao, Osumi, et al., 2010), these initial investigations on dissonance suggest that the MPFC—in concert with several other cortical and subcortical regions —may play a role in decision-induced attitude change (Izuma et al., 2010; Jarcho et al., 2011; Qin et al., 2011).

This emerging research on dissonance is relevant because it helps to further characterize the nature of integrative processes within SDT and also helps to articulate directions for future research. One perspective on cognitive dissonance that helps frame the current discussion is self-affirmation theory (Steele, 1988). Self-affirmation theory is predicated on the idea that people are motivated to maintain a positive self-image and posits that dissonance-induced attitude change occurs as people work to defensively maintain the integrity of their self-concept. Although we are unaware of any research directly examining the association between need satisfaction and cognitive dissonance, previous research in SDT shows that need satisfaction aids in the development of healthy, nondefensive forms of self-evaluation (Deci & Ryan, 1995). We accordingly suspect that need satisfaction should promote greater tolerance of postdecisional dissonance and thereby mitigate the motivation to defensively restore self-esteem. Indeed, postdecisional dissonance may not even occur among people with higher levels of need satisfaction as such individuals may experience their otherwise dissonant cognitions as an opportunity for self-exploration (Deci & Ryan, 1985). Accordingly, the present research suggests that the heightened MPFC activation observed in dissonance research bespeaks its general role in the resolution of decisional conflict (Nakao et al., 2009; Nakao, Osumi, et al., 2010) and not necessarily its role in the reduction of dissonance per se. Future research examining the neural correlates of dissonance may benefit from considering an individual difference perspective founded upon SDT's concept of basic psychological needs. For complementary reasons, future research examining the neural underpinnings of integrative processes may benefit from adapting the experimental paradigms utilized in dissonance research.

The current study may also bear important implications for applied research. Practitioners informed by the principles of SDT have used the concept of basic psychological needs as an organizing principle in the design of targeted interventions for a variety of applied contexts (e.g., workplace environments, educational contexts, clinical settings, etc.; Deci & Ryan, 2000, 2008, 2011). Such interventions have been shown to be reliably associated with the development of optimal forms of motivation, greater persistence and performance, and higher levels of well-being. The current study was preliminary in the sense that it was not designed to assess whether need satisfaction predicts greater success in the regulation of decisional conflicts; rather, the primary aim of our experiment was to examine the effect of need satisfaction on MPFC activity across levels of decisional conflict. The present results, however, do encourage us to speculate that one mechanism through which need-facilitating environments could foster the development of improved self-regulatory capacities is by aiding in the establishment self-knowledge frameworks (i.e., clear goal priorities, narrative coherence, etc.). Self-knowledge frameworks may function as strong neural inputs to more effectively guide one's behavior in the face of competing response affordances in a manner that one deems to be personally appropriate (cf. Hirsh, Mar, & Peterson, 2012; Nakao, Mitsumoto, et al., 2010; Nakao, Osumi, et al., 2010). It may thus prove fruitful for future research on basic psychological needs to specifically investigate the possible mediating role of MPFC function in the prediction of real-world behavioral outcomes.

We believe that the present findings represent an important step forward in conceptual and empirical work on integrative processes. Although integrative processes are, in principle, amenable to neurobiological investigation (Ryan & Deci, 2006; Ryan et al., 1997), empirical work has mostly targeted the experiential level of analysis (Deci & Ryan, 2011), and research has only just begun to investigate integrative processes at the level of the brain. Drawing a connection between need satisfaction and self-referential processing mediated in the MPFC provides future researchers with an empirically established "point of entry" for further examining the neural basis of integrative tendencies. Above all else, we believe this is the most important contribution of the present research. In conclusion, the present research was the first attempt to explicitly examine the effects of basic psychological need satisfaction at the level of the brain, and the results of this study provide a new type of evidence for the existence of integrative processes.

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