Neural cultural fit: non-social and social flanker task N2s and well-being in Canada

Matthew Joseph Russell 1,2,3 · Liman Man Wai Li 4 · Hajin Lee 2 · Anthony Singhal 2,5 · Takahiko Masuda 2

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Abstract

Research has noted well-being benefits to having a cultural fit between a person and the environment. The more a person fits the environment, the greater their reported well-being. We tested if cultural fit is also seen with neural patterns, which we term neural cultural fit. To address this question, we measured European Canadian (EC) and East Asian (EA) electroencephalography data during non-social (switches) and social (face emotions) flanker tasks. Participants were asked to categorize center switches (up–down) and faces (happy–sad) that were surrounded by other switches or faces. The flanker tasks involved congruent lineups, which showed the same directions or emotions between center and surrounding stimuli, and incongruent lineups, with different directions or emotions between center and surrounding stimuli. As the target neural measure, we calculated N2 event related potentials. Larger N2s to incongruent than congruent lineups suggest more conflict to incongruent lineups. We found larger N2s to incongruent than congruent lineups for EAs, as compared to ECs, replicating previous findings showing more context sensitivity for EAs. We also found evidence of neural cultural fit, with individuals with more difference from N2 neural pattern averages set by ECs in Canada in the social task, reporting less well-being. Cultural fit was also observed with social orientation beliefs, but did not explain neural cultural fit. These findings are important as they suggests that cultural fit depends not only on the subjective experience of what we believe (e.g., self- reports), but also on the objective experience of how we think (e.g., neural patterns).

Introduction

As social creatures, humans thrive through their relationships with other people (Cohen and Wills 1985; Kaplan et al. 1977; Woolcock and Narayan 2000). Some argue that social relationships are so important that the human brain evolved to understand others (e.g., Dunbar and Shultz 2007; Powell et al. 2010). We even find evidence of neural pathways that have developed to be sensitive to not fitting in with others in our social surroundings (e.g., Eisenberger and Lieberman 2004). This sensitivity to fitting in with others has implications on our health, with a lack of fit between individuals and surrounding social environments associated with less well- being (e.g., Li and Hamamura 2010). This phenomenon is called cultural fit and is thought to extend to a wide range of domains; well-being has been shown to be connected to the fit between individual values and surrounding values from universities (Gloria et al. 2005; Gloria and Kurpius 1996), areas of study (Sagiv and Schwartz 2000), and societies (Li and Bond 2010; Li and Hamamura 2010; Ward and Chang 1997).

Cultural Fit

Li and Hamamura (2010) found evidence of cultural fit for societal-level characteristics. Individuals with more collectivist beliefs (group focused) reported greater lev- els of well-being in collectivistic societies, whereas this was not seen in individualist (individual focused) societies. Ward and Chang (1997) proposed that discrepancy from majority cultural patterns leads to cultural-fit issues. They measured how much personality patterns for Americans living in Singapore differed from local Singaporean personality averages and found that larger discrepancies from majority cultural patterns were related to more reports of depressive symptoms. Both of these findings suggest that cultural beliefs measured in self-reports can relate to well-being, which we label cultural belief fit for this paper.

Our research extends this body of research to investigate if well-being is related to a fit with surrounding culture neural patterns, which we term neural cultural fit. This research is important as it would suggest that beyond what we believe (e.g., self- reports), how we think [e.g., through event related potentials (ERPs)] is important to well-being. This is important as self-report has been noted to have various short- comings, including a reliance on comparison groups (Heine et al. 2002). This problem may affect cultural belief fit research, where we sometimes find evidence for cultural belief fit (e.g., Gloria et al. 2005; Li and Hamamura 2010; Ward and Chang 1997) and sometimes against it (e.g., Ward and Searle 1991). This research seeks to overcome issues related to self-report. Moreover, this research seeks to investigate if cultural belief fit differs from neural cultural fit, as recent research has highlighted how neural and self-report measures sometimes measure different processes. ERPs are thought to measure earlier automatic attention processes and self-reports later deliberate processes, and these processes often diverge (e.g., Goto et al. 2010, 2013; Russell et al. 2018). *As the primary goal of this research, we investigated if a fit between individuals and majority cultural neural patterns was related to well-being. We also investigated if neural cultural fit explained processes beyond cultural belief fit.*

Culture and neural patterns

As a potential basis for neural cultural fit, ERP research has noted many cultural differences in ERP neural patterns (Goto et al. 2010, 2013; Lewis et al. 2008; Masuda et al. 2014; Na and Kitayama 2011; Russell 2016; Russell et al. 2015, 2018). This research has found that East Asians (EAs; e.g., Asian Americans) tend to be more sensitive to non-social and social context than North Americans. Our research sought to replicate these culturally specific neural patterns and determine if they were connected to well-being, providing evidence of neural cultural fit.

The flanker task and the N2

Our research used the flanker task to measure neural context sensitivity to non-social and social tasks. The flanker task has participants quickly classify center figures (e.g., arrows), when the center figures are surrounded by congruent (i.e.,<<<<<) or incongruent flankers (i.e.<<><<). Research with flanker tasks (for correct responses) often focuses on the N2 (e.g., Yeung et al. 2004). A stronger N2 is found for incongruent lineups than congruent lineups, termed the N2 incongruity effect. The N2 incongruity effect is thought to reflect increased conflict to the perceptually incongruent flankers (Yeung et al. 2004). Research has found evidence that a N2 incongruity effect is found for both EAs (e.g., Chinese) and North Americans (e.g., Americans), and is present in some capacity for non-social and social flanker tasks (e.g., Liu et al. 2013; Yeung et al. 2004). However, as previous research did not compare flanker tasks between North Americans and EAs, we do not know how much each culture experiences conflict in either flanker task.

As a secondary goal of this research, we investigated if neural patterns related to context sensitivity for North American and East Asian cultures were seen in both non-social and social flanker tasks. We investigated both non-social and social tasks as previous research has suggested that behavioral cultural differences are more salient in social tasks than non-social tasks (Ito et al. 2013); however, recent cultural neuroscience research also suggested that EAs are more context sensitive than North Americans on both types of tasks (Goto et al. 2010, 2013;

Lewis et al. 2008; Masuda et al. 2014; Russell 2016; Russell et al. 2015, 2018). *We also explored whether neural cultural fit was present in either or both tasks.*

Hypotheses

Our research examined if evidence for neural cultural fit was seen for European Canadians (ECs) and EAs living in Canada during non-social and social flanker tasks. For our target neural measure, we measured N2 patterns to non-social (up–down arrows) and social flankers (happy–sad lineups). For neural cultural fit, we measured if well-being was connected to discrepancies from average cultural N2
patterns set by ECs and EAs.

Hypothesis 1 Based on previous evidence of cultural belief fit (Li and Hamamura 2010; Searle and Ward 1990; Ward and Chang 1997), we expected that a fit with majority culture (ECs) neural patterns in Canada would predict more reported well- being for individuals living in Canada (Hypothesis 1a). We explored if neural cultural fit was connected to either or both non-social and social tasks (Hypothesis 1b). We also explored if cultural belief fit explained neural cultural fit findings (Hypothesis 1c).

Hypothesis 2 Due to previous cultural neuroscience findings showing that EAs are more context sensitive (Goto et al. 2010, 2013; Lewis et al. 2008; Nisbett 2003), we expected that EAs would show stronger N2 incongruity effects in both the non- social and social task, when compared to ECs.

Methods

This research was approved by the University of Alberta Ethics Board in accordance to the Declaration of Helsinki. Written consent was obtained from all participants.

Participants

We collected data from 44 EC and 43 EA (i.e., Japanese, Chinese, and Korean) undergraduate students from a Canadian university. ECs were born in Canada and were not of EA descent. EA participants had been living in Canada for at least 1 year to ensure sufficient language proficiency and experience with Canadian life, and up to 6years as research suggests that cultural differences are reduced with earlier immigration (Cheung et al. 2010). We collected at least 20 participants per group based on previously established neuroscience participant numbers on flanker tasks where N2s were measured (Liu et al. 2013; Yeung et al. 2004).

For ECs, 22 were randomly assigned to the non-social condition (10 females, 12 males; ages 20.6±6.5, range=17–48 years) and 22 were assigned to the social condition (11 females, 11 males; ages 19.0±1.8, range=17–26 years). For EAs, 21 were randomly assigned to the non-social condition (12 females, 9 males; ages 20.6±2.0, range=18–25 years) and 22 were assigned to the social condition (13 females, 9 males; ages 20.0±1.3, range=18–23 years). In addition, 6 EC (2 non- social and 4 social) and 4 EA (2 non-social and 2 social) participants took part in sessions but were rejected due to data collection issues (i.e., electrode problems, too many movements, or problems with task completion). To ensure adequate under- standing of the task for all participants, multiple question prompts were provided throughout the task, as well as two sets of practice trials. All participants earned partial course credit and gave us written informed consent.

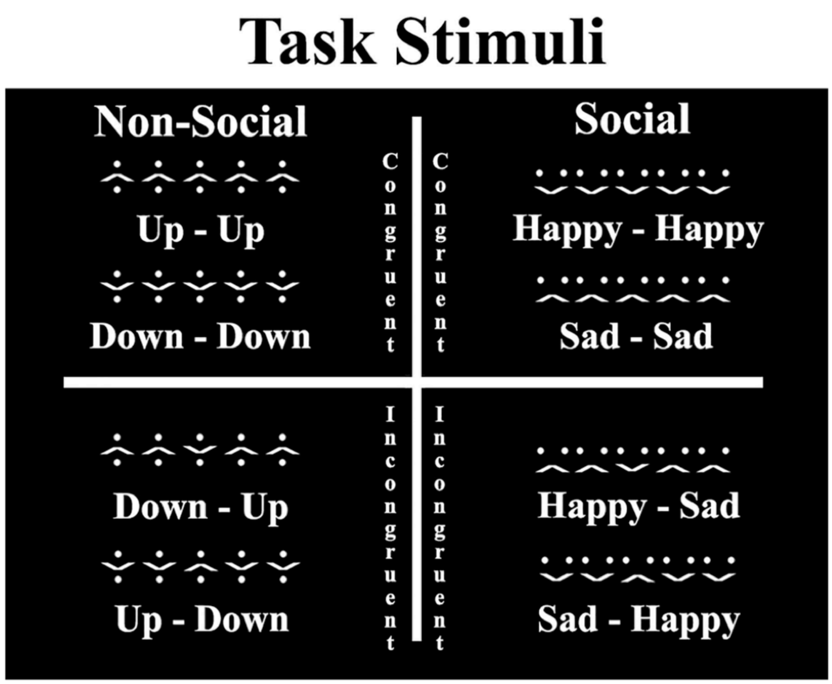

Fig. 1 Sample non-social and social flanker task stimuli for the congruent and incongruent conditions

Flanker task stimuli

Lineups consisted of five up and down arrows and two dots placed near each arrow. For non-social stimuli, one dot was placed above and one dot was placed below the arrow and the stimuli were framed to be up or down switches. For social stimuli, both dots were placed above the arrow and the stimuli were framed to be happy and sad faces. We used emotional faces for the social task as emotions are thought to be social processes (e.g., Russell et al. 2015, 2018). Non-social and social flanker task stimuli were created to be as similar as possible to control for possible differences in processing that might be due to how stimuli were perceived (see Fig. 1 for example stimuli). We did this to ensure that observed neural pattern differences were due to the perception of non-social and social stimuli, and not to differences in processing for the type and amount of information presented. Lineups with the same emotions or directions for the center stimuli and the four surrounding stimuli were classified as congruent (e.g., the center face and the background faces were happy), and lineups with differing emotions and directions for the center stimuli and the four surrounding stimuli were classified as incongruent (e.g., the center switch was up, but the background switches were down; see Fig. 1).

Lineup presentation was randomized with E-prime 2.0 Professional (Psychology Software Tools, Inc., Pittsburgh, PA) between sets of eight lineups, consist- ing of two sets of all four possible combinations of the up/down or happy/sad lineups. In total, besides two practice rounds, which involved 24 practice trials each round, the task involved 384 lineup presentations (192 congruent and 192 incongruent lineups).

Procedure

Sessions took place in an electrically shielded, sound-proofed room at the University of Alberta. After providing consent and being prepped for electroencephalography (EEG) data collection, participants were randomly assigned to either the non-social or social condition and seated approximately 50 cm from a 20.1″ LCD monitor that displayed task instructions and stimuli from a computer running E-prime 2.0 Professional (Psychology Software Tools, Inc., Pittsburgh, PA). This created an 8.7° by 2.2° visual angle with flanker stimuli. EEG data were recorded simultaneously on a separate computer through Netstation 4.2 (Electrical Geodesics, Inc., Eugene, OR).

Before collecting EEG data, participants were first instructed on the nature of the task and how/when to make movements. Participants were told that their task was to classify the direction of the center switch (non-social task) or the center face (social task). Classification for up/down or happy/sad center stimuli required a push to the A or the L key, and participants were told to judge the center stimuli “as quickly and accurately as possible”. Keys were counterbalanced to ensure that this did not influence reaction time (RT) to the task. After being instructed on the nature of the task, participants were provided with 2 practice rounds (24 trials each; 1 with feedback and 1 without) to become accustomed to the task, while experimenters provided feedback and answered questions to ensure that participants understand the task. For feedback, the first practice round displayed “INCORRECT” for wrong answers and “No response detected” when participants answered over the 800 ms allowed answer time. Participants then proceeded to the main task. Participants were provided with a 10-s break after classifying 64 stimuli in the main task (5 total breaks) and were encouraged to take as much time as they wanted in these breaks to recover. On completion, participants answered questionnaires, before being debriefed and dismissed.

Trial timing

Our stimulus presentation was based on previous research (Kitayama and Park 2014), and was adjusted through pilot testing to minimize task fatigue. Each trial included (in order): (1) a brief presentation of a fixation cross (+) for 100 ms, (2) a brief blank screen randomly jittered between 100 and 500 ms, (3) the presentation of the flanker stimuli for 200 ms, (4) a maximum answer time of 800 ms for each stimuli, which advanced to step #5 when participants answered or if this time elapsed, and a (5) a blank screen for 800 ms to recover eye fatigue (see Fig. 2 for trial timing).

Electroencephalography (EEG) recording, processing and analyses

EEG data were recorded using a high-density 256-channel Geodesic Sensor Net (Electrical Geodesics, Inc., Eugene, OR), amplified at a gain of 1000 and sam- pled at 250 Hz. Impedances were kept below 50 kΩ. EEG data were initially referenced to the vertex electrode (Cz) but digitally average re-referenced offline.

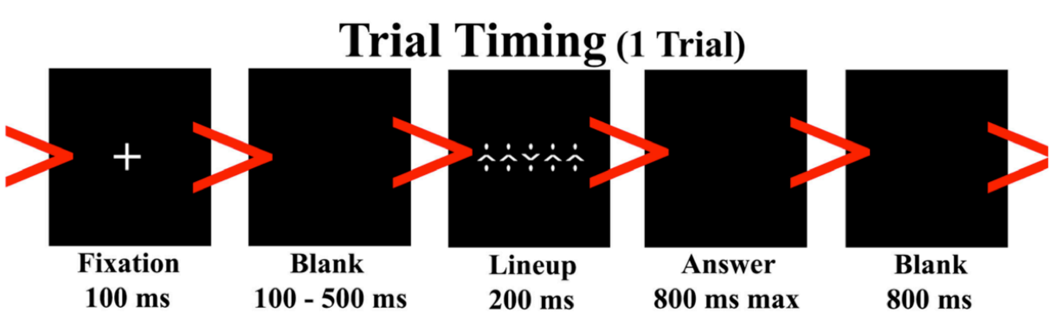

Fig. 2 Timing for one trial of the flanker task

Data were analyzed by custom MATLAB scripts in conjunction with the open- source EEGLAB toolbox (Delorme and Makeig 2004, http://sccn.ucsd.edu/eegla b). Signal was digitally bandpass filtered between 0.5 and 30 Hz. Artifacts were corrected via principal component analysis (PCA; e.g., Hoffman and Falkenstein 2008; Luck 2005). To improve the quality of PCA components for selection, continuously bad channels were rejected and interpolated at the end of preprocessing using splines. Participants were rejected if more than 20% of the channels were rejected, many channels in the target analyses were rejected, or PCAs showed noticeable effects from the rejected channels. Finally, trials for which voltage deviated more than 300 μV from baseline were rejected.

All trials were segmented to include a 200-ms pre-stimulus baseline. Based on topographies (see Fig. 3) and previous research that has shown differences in conflict processing in social flanker-like tasks in the frontal and central electrodes (Russell et al. 2018), dipoles were calculated as frontal and central clusters. Dipoles were averaged across participants, with the N2 quantified as an average of electrodes for frontal (cluster includes F3, Fz, F4, F7, and F8) and central (includes C3, Cz, and C4) clusters of electrodes (see Fig. 4 for electrode clusters). Based on previous research, the mean voltage was taken over the 300–400 ms time window post-stimulus, when participants correctly identified central stimuli (Yeung et al. 2004). Statistical analyses were carried out using Matlab 7.1 (MathWorks, Natick, MA, USA) and SPSS Statistics, Version 25.0.0.1 (SPSS, Inc., 2019, Chicago, IL).

Manipulation check

We included three items to check if our manipulation was successful. For the social task, we included a single item “when engaging in the emotion task, I perceived the objects as faces.” For the non-social task, we included two items (1) “when engaging in the switch task, I perceived the objects as switches,” and (2) “when engaging in the switch task, I perceived the objects as faces.” We included the second item to ensure that the objects were not mistakenly being perceived as social. Participants rated each item on a Likert-scale ranging from 1 (Strongly disagree) to 7 (Strongly agree).

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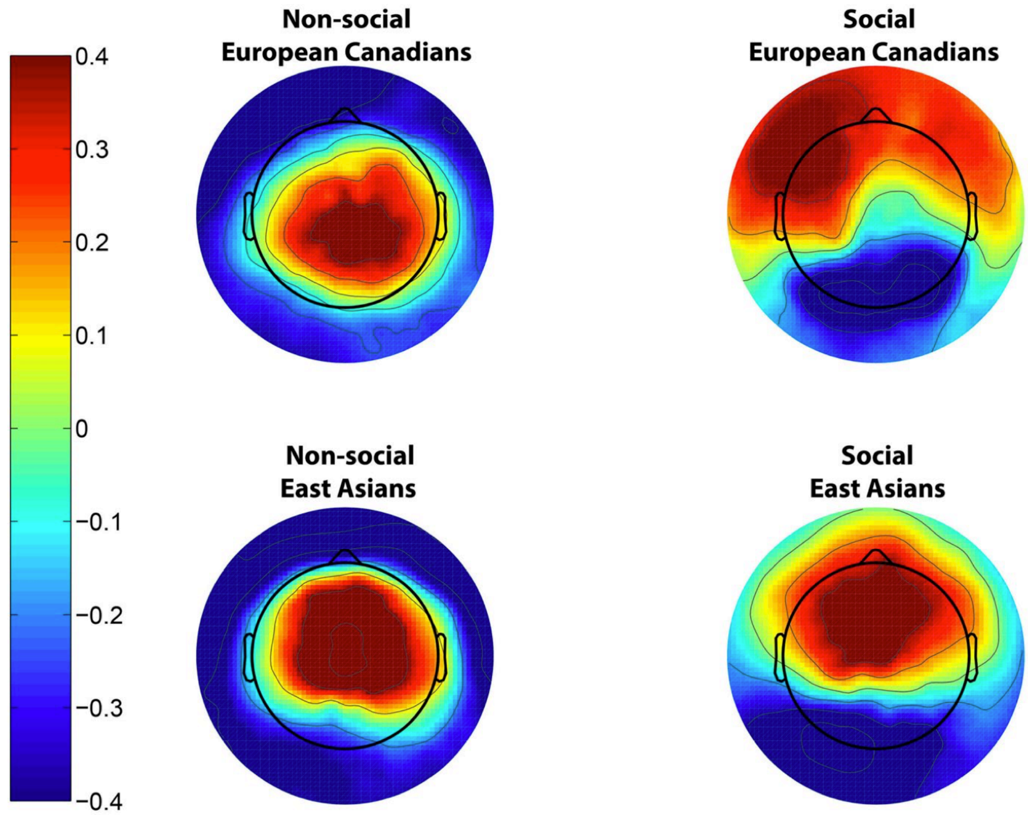

Self-report measures

To measure cultural belief fit we used a measure often used to distinguish ECs from EAs, social orientation (Singelis 1994). To measure well-being we used the Satisfaction with Life Scale (Diener et al. 1985).

Cultural beliefs: independent and interdependent social orientation

Individuals' independent and interdependent social orientation beliefs were assessed with the 24-item Singelis self-construal scale (12 independence items and 12 interdependence items; Singelis 1994). Participants rated each item on a Likert-scale ranging from 1 (Strongly disagree) to 5 (Strongly agree). Sample items for the independence sub-scale are, "Being able to take care of myself is a primary concern for me," and "I enjoy being unique and different from others in many respects," and sample items for the interdependence sub-scale are, "It is important to me to respect decisions made by the group," and "My happiness depends on the happiness of those around me". Reliabilities for each sub-scale

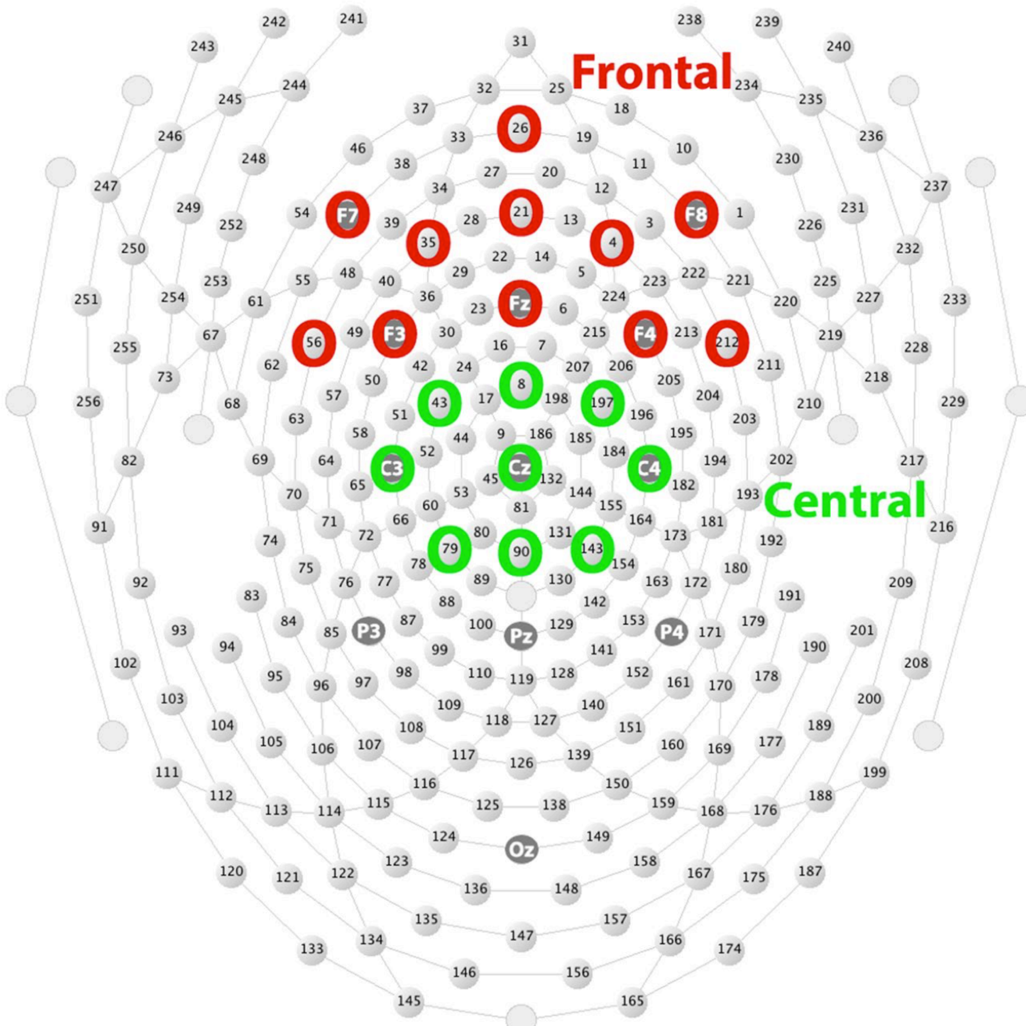

Fig. 4 Frontal and central electrode cluster electrodes

were fair (Independence: EC Cronbach's α=.56 and EA α=.51; Interdependence: EC Cronbach's α = .74 and EA α = .68).

Well-being

Well-being was assessed with a 5-item Satisfaction with Life Scale (SWLS; Diener et al. 1985). Participants rated each item on a Likert-scale ranging from 1 (Strongly disagree) to 7 (Strongly agree). Sample items are, “I am satisfied with my life,” and “The conditions of my life are excellent.” Reliabilities for this scale were satisfactory across cultures (EC Cronbach’s α=.76, and EA α=.68).

Results

Manipulation Check

We performed one-sample t-tests, comparing ratings to the midpoint [a 4 (a neu- tral rating)]. For the social task, that involved facial emotion classification, participants strongly endorsed that they saw faces, $t(43)=8.59$, $p<.001$, Cohen’s $d=1.29$ ($M=5.95$, $SD=1.51$). For the non-social task, that involved switch direction classification, participants were neutral in their endorsement of the stimuli as switches, $t(42)=.08$, $p=.94$, Cohen’s $d=-.01$ ($M=3.98$, $SD=1.93$); however, they strongly disagreed that they saw faces, $t(42)=9.61$, $p<.001$, Cohen’s $d=1.46$ ($M=1.91$, $SD=1.43$). These results provide evidence that there was a discrimination between the social and non-social tasks. Despite the lower values for the non-social task’s ability to be seen as switches, the fact that they were not perceived as faces provides evidence that it was not seen as social.

Behavioral Analyses

For our first set of analyses, we compared RT and accuracy effects commonly paired with flanker tasks (Folsten and Petten 2008; Yeung et al. 2004). This analysis was done to establish validity of the tasks.

Reaction time

For our first RT analysis, we calculated the average RT across the different types of stimuli for each of the tasks, removing incorrect or missing trials (i.e., the combined average of the happy/happy, sad/sad, happy/sad, and sad/happy judgment RTs). In a 2 (Culture: ECs vs. EAs) by 2 (Condition: Non-social vs. Social) ANOVA, with average RT as the measure, we only found a significant main effect of Culture, $F(1, 83)=7.90$, $p=.006$, partial $\eta2=.09$, revealing that EAs were faster on the task than ECs (ECs $M=302.07$ ms, $SD=76.83$; EA $M=262.79$ ms, $SD=52.44$). The main effect of Condition, $F(1, 83)=.21$, $p=.65$, partial $\eta2=.03$, and the interaction of Culture and Condition were not significant, $F(1, 83) = 2.32$, $p = .13$, partial $\eta2 = .03$.

For our second RT analysis, we calculated the reaction time incongruity effect, as the average of the difference between incongruent and congruent lineup RTs for each participant, removing incorrect or missing trials (i.e., the average of the happy/ sad−happy/happy and the sad/happy−sad/sad RTs). In a 2 (Culture: ECs vs. EAs) by 2 (Condition: Non-social vs. Social) ANOVA, with RT incongruity effect as the measure, we only found a significant main effect of Condition, $F(1, 83)=23.49$, $p<.001$, partial $\eta 2=.22$, revealing that people had larger incongruity effects to the non-social task than the social task (non-social M=33.57 ms, SD=17.74; social M=14.60 ms, SD=18.84). This may suggest that the incongruent non-social flankers were more distracting to participants than in the social task. The main effect of Culture, $F(1, 83)=2.91$, $p=.09$, partial $\eta 2=.03$, and the interaction of Culture and Condition were not significant, $F(1, 83) = .63$, $p = .43$, partial $\eta 2 = .008$.

Accuracy

For our first accuracy analysis, we measured average accuracy across the different types of stimuli (i.e., the combined average of happy/happy, sad/sad, happy/sad, and sad/happy RTs). In a 2 (Culture: ECs vs. EAs) by 2 (Condition: Non-social vs. Social) ANOVA, with accuracy as the measure, the main effect of Condition, $F(1, 83)=1.19$, $p=.28$, partial $\eta 2=.01$, and of Culture, $F(1, 83)=1.86$, $p=.17$, partial $\eta 2=.02$, and the interaction of Culture and Condition were not significant, $F(1, 83) = 1.45$, $p = .23$, partial $\eta 2 = .02$. Overall, participants had a high overall accuracy in both tasks (92%; SD 5%), providing evidence that they performed well on the tasks.

For our second accuracy analysis, we calculated the accuracy incongruity effect, as the average of the difference between congruent and incongruent lineup accuracies for each participant (i.e., the average of happy/happy−happy/sad and sad/ sad−sad/happy accuracies). In a 2 (Culture: ECs vs. EAs) by 2 (Condition: Non- social vs. Social) ANOVA, with RT incongruity effect as the measure, we found only found a significant main effect of Condition, $F(1, 83)=5.92$, $p=.02$, partial $\eta 2=.07$, revealing that people had larger incongruity effects to the non-social task than the social task (non-social M=.07, SD=.07; social M=.03, SD=.06). The main effect of Culture, $F(1, 83) = 1.35$, $p = .25$, partial $\eta 2 = .02$, and the interaction of Culture and Condition were not significant, $F(1, 83) = .28$, $p = .60$, partial $\eta 2 = .003$.

Behavioral results summary

The behavioral results showed larger incongruity effects for the non-social task than the social task and high overall accuracy on the tasks for both groups. In addition, EAs showed faster overall performance on the tasks than ECs. This finding is in line with research showing that EAs are faster at simple tasks involving contextual information (Li et al. 2014; Wang et al. 2012).

N2 analysis

For N2 analyses, we calculated N2 incongruity effects, as the difference between incongruent and congruent N2s in the 300–400 ms time range for previously described electrode clusters (Fig. 5 for ERP waveforms).

We used a 2 (Location: Frontal cluster vs. Central cluster; within-subjects) by 2 (Culture: ECs vs. EAs) by 2 (Condition: Non-social vs. Social) ANOVA, with N2 incongruity effect as the measure. For this analysis, we found a significant main effect of Culture, $F(1, 83)=5.15$, $p=.03$, partial $\eta 2=.06$, revealing EAs generally had larger incongruity effects than ECs (EAs M = .38 μV, SD = .38; ECs M = .18 μV, SD=.45). We also found a significant interaction of Location and Condition, $F(1, 83)=14.51$, $p<.001$, partial $\eta 2=.15$. The main effect of Location, $F(1, 83)=1.74$, $p=.19$, partial $\eta 2=.02$, and Condition, $F(1, 83)=.38$, $p=.54$, partial $\eta 2=.02$, were not significant. Similarly, the interaction between Culture and Condition, F(1,

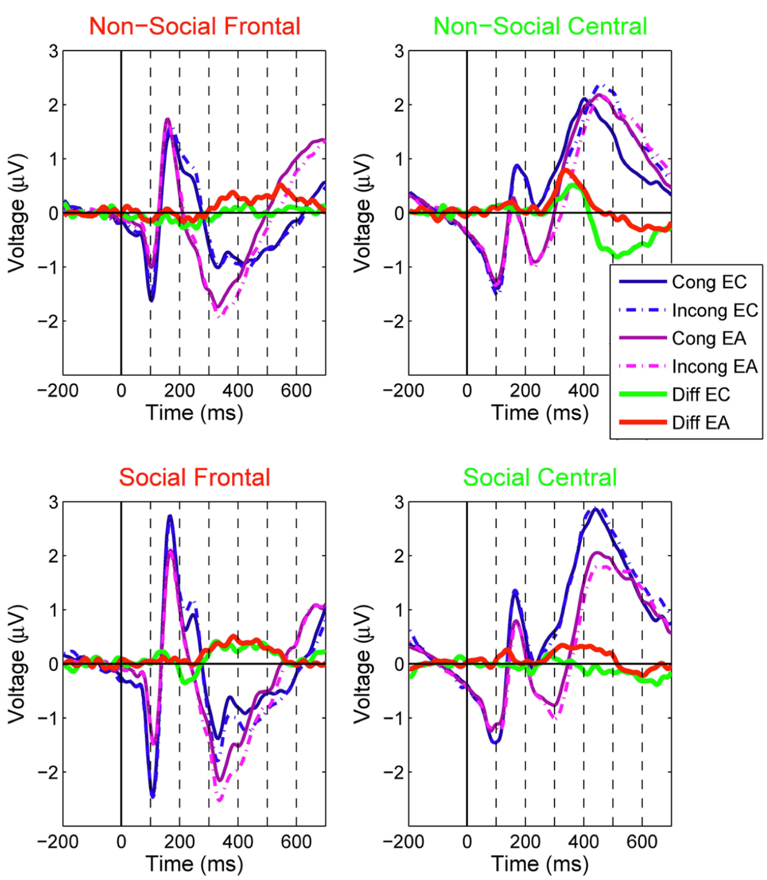

Fig. 5 ERP waveforms for frontal and central electrode clusters. European Canadian (EC), East Asian (EA) average ERPs for these electrode clusters and their difference (Diff: congruent − incongruent; the N2 incongruity effect) are shown for the non-social (top) and social (bottom) conditions

83) = .07, $p = .79$, partial $\eta 2 = .001$, Location and Culture, $F(1, 83) = .55$, $p = .46$, partial $\eta 2=.007$, and Location, Culture and Condition, $F(1, 83)=.61$, $p=.44$, partial $\eta 2 = .007$, were not significant.

We further investigated what drove the interaction between Location and Condition. Splitting by Condition, we found that while the center N2 incongruity effect was larger than the frontal N2 incongruity effect for the non-social condition, $t(42)=-3.00$, $p=.005$, Cohen's d=.58 (Frontal M=.11, SD=.56; Central M=.50, SD=.77), the frontal N2 incongruity effect was larger than the central incongruity effect for the social condition, $t(32) = 2.40$, $p = .02$, Cohen's d = .47 (Frontal M = .35, SD=.43; Central M=.16, SD=.37). This provides evidence that the two flanker tasks might engage different neural processes.

N2 results summary

A larger N2 incongruity effect for EAs indicates increased conflict to surrounding context than for ECs (Yeung et al. 2004). This replicates previous findings showing increased context sensitivity for EAs (Goto et al. 2010, 2013; Lewis et al. 2008; Nisbett 2003; Russell et al. 2015, 2018).

Majority neural fit

As our main measure of neural cultural fit, we calculated scores that reflected discrepancy from the cultural patterns set by the majority culture group in Canada in the data, ECs, as discrepancy measures have been used in previous research on cultural belief fit (e.g., Ward and Chang 1997). For our neural measure, we used the average N2 incongruity effect over the frontal and central regions. ECs majority culture neural pattern averages were .19 μV for the non-social task and .16 μV for the social task. As a measure of how much individual's neural patterns fit the cultural patterns set by ECs, we calculated individuals' discrepancy from the EC averages in N2 incongruity effects (as the absolute value of the average EC N2s minus individuals' N2s).

Related to our hypotheses, we performed a regression analysis entering mean-centered discrepancy scores, condition, and the interaction of discrepancy score and condition on predicting well-being scores. Results of this combined analysis found an interaction of discrepancy score and condition in predicting well-being (standardized) $\beta=-.32$, $p=.007$, Cohen's $f2=.12$. Discrepancy was also a significant predictor in the model, $\beta=-.36$, $p=.004$, Cohen's $f2=.15$, but condition ($\beta=-.09$, $p=.42$, Cohen's $f2=.01$) was not a significant predictor. Further investigating what drives the interaction of condition and discrepancy on well-being, we split by condition and found that discrepancy scores only predicted well-being in the social task

(social: $\beta = -.46$, $p = .002$, Cohen's $f2 = .27$; non-social $\beta = -.03$, $p = .86$, Cohen's $f2 = .002$), with those with greater reported discrepancy scores reporting less well- being. This provides evidence that neural cultural fit was only seen for the social task. In addition, a regression analysis for culture, discrepancy score, and the inter- action of discrepancy score and culture in predicting well-being, was not significant for the interaction of discrepancy score and culture ($\beta = -.002$, $p = .99$, Cohen's
$f2 < .001$).1, 2.

Minority neural fit

We also checked if adherence to minority N2 neural patterns related to well-being. For this analysis, we calculated scores that reflected discrepancy from the cultural patterns set by a minority culture group in Canada, EAs. For our neural cultural fit comparison point, we used EAs' average central N2 incongruity effects for the non- social and social tasks (.42 μV and .34 μV; respectively). As a measure of how much individual's neural patterns fit the cultural patterns set by EAs, we calculated individuals' discrepancy from the EA averages in N2 incongruity effects (as the absolute value of the average EA N2s minus individuals' N2s).

Related to our hypotheses, we performed a regression analysis entering mean-centered discrepancy scores, condition, and the interaction of discrepancy score and condition on predicting well-being scores. This analysis found no relationships significant (discrepancy: $\beta = -.07$, $p = .61$, Cohen's $f2 = .004$; condition: $\beta = .03$, p = 81, Cohen's $f2 < .001$; discrepancy × condition: $\beta = .05$, $p = .97$, Cohen's $f2 = .003$). In addition, a regression analysis for culture, discrepancy score, and the interaction of discrepancy score and culture in predicting well-being, was not significant for the interaction of discrepancy score and culture ($\beta = .03$, $p = .79$, Cohen's $f2 < .001$).

Neural cultural fit summary

This analysis provides evidence that neural cultural fit operates in the domain of majority cultural patterns, as EA minority cultural patterns did not affect EAs' or ECs' well-being. Only people that followed Canadian majority culture neural patterns for social judgments (and not non-social judgments) reported greater levels of well-being.

Cultural belief fit

Last, we checked if cultural belief fit (with social orientation) was observed and if it explained the neural cultural fit findings.

To target cultural differences in beliefs for these analyses, we first quantified differences in independence and interdependence social orientation beliefs for the two groups. Using an independent samples t test, we found a significant difference between the two cultures' independence social orientation beliefs, $t(84)=3.53$, $p<.001$, Cohen's $d=.75$ (EC $M=3.54$, $SD=.44$; EA $M=3.23$, $SD=.39$). On the other hand, there was no difference for interdependence social orientation beliefs, $t(84)=.60$, $p=.55$, Cohen's $d=.11$ (EC $M=3.67$, $SD=.50$; EA $M=3.62$, $SD=.43$). These findings replicate previous findings, showing cultural differences in social orientation are most salient in independence for ECs and EAs (Russell et al. 2015, 2018).

We then measured how well-being related to independence discrepancy scores, because cultural differences were most salient in this domain. We calculated cultural belief discrepancy scores based on independence social orientation cultural aver- ages (e.g., the absolute value of the difference from individual's beliefs from the EC mean=3.67 and the EA mean=3.62). In this analysis, we found that while EC discrepancy scores did not relate to well-being ($r=-.069$, $p=.53$, $R2=.004$), EA discrepancy scores did ($r = .41$, $p < .001$, $R2 = .17$). The more people's independence beliefs differed from minority (EA) cultural beliefs in Canada, the more well-being they reported. To further understand this pattern, we performed a correlation analysis between raw independence scores and well-being, finding that more independent individuals reported more well-being ($r=.47$, $p<.001$, $R2=.22$). As Canada is noted to follow independence social orientation, these results replicate previous cultural belief fit findings that suggest that following majority cultural beliefs relates to more well-being (Li and Hamamura 2010; Ward and Chang 1997).3

Finally, we explored whether neural cultural fit brings additional predictive power to explain well-being after considering the effect of cultural beliefs. We per- formed a partial correlation analysis on the previously noted significant relationship between EC N2 discrepancy scores and well-being, controlling for the significant minority (EA) cultural belief discrepancy scores. N2 discrepancy score relation- ships remained significant after correcting for minority cultural belief discrepancy scores (Combined neural pattern discrepancy score social: not-controlling: $r = -.46$, $p = .002$, $R2 = .21$; controlling: $r = -.40$, $p = .008$, $R2 = .16$). This suggests that neural cultural fit may explain a part of well-being beyond cultural belief fit.4

Discussion

Culture, non-social and social context sensitivity

We found that larger N2 incongruity effects were seen for EAs in both the non- social and social flanker tasks (Hypothesis 2). This N2 incongruity effect finding is in line with recent findings showing stronger incongruity effects for EAs than North Americans, and provides evidence that these differences apply to both non- social and social flanker tasks (Goto et al. 2010, 2013; Lewis et al. 2008; Russell et al. 2015, 2018). In addition, we found an interaction of location and condition. While participants had larger central (vs. frontal) N2s for the non-social task, they had larger frontal (vs. central) N2s for the social task. We should note that in social tasks the presence of a frontal N2 for both cultures and central conflict only for EAs has been noted in previous research (Russell 2016; Russell et al. 2018). Moreover, further analysis on the current data (see Supplementary Analysis) showed this same pattern. As the Supplementary Analysis also found that central regions were most correlated with conflict related behaviors, this might suggest that frontal and central N2s in the social task represent separate neural process. Based on these findings, the frontal effect may be more related to emotional processing and the central region more related to conflict. However, future research is necessary to truly understand the potential differences in neural processing for the two tasks.

Evidence for neural cultural fit

Most importantly, this research provides initial evidence of the presence of neural cultural fit (Hypothesis 1a) for social tasks, but not non-social tasks (Hypothesis 1b). Showing similar neural patterns to majority culture neural patterns for the social flanker task predicted well-being for both EAs and ECs living in Canada. These findings were not explained by cultural belief fit (Hypothesis 1c). Furthermore, these findings were not explained by fit with either culture's behaviors (see Footnote 3). These findings add to the field as they suggest that our thought patterns are linked to our well-being. This research is important as it suggests that beyond the subjective realm of what we believe (e.g., self-reports) and how we act (e.g., behaviors), neural patterns related to how we think (e.g., seen through ERPs) is important to well- being. This pattern may suggest potential interventions for culture-based struggles based on basic thought patterns. Interventions based on thought patterns may be easier to implement than those targeting beliefs, as beliefs may be seated in deep culturally influenced worldviews.

That neural cultural fit was only seen for social tasks (and not non-social tasks) suggests that it might operate in a nuanced fashion. This nuance is in line with recent cultural neuroscience research suggesting that culture may operate differently based on contextual factors (e.g., Fong et al. 2014; Russell et al. 2018). This pattern was seen in an individualistic country, in contrast to previous findings which found cultural belief fit only in collectivist cultures (Li and Hamamura 2010), and may suggest that a form of cultural fit operates in both cultural contexts. As a last consideration, an important nuance of these findings is that neural cultural fit generalized to both ECs and EAs in Canada. As such, these findings may be applied to both marginalized ECs and EA sojourners, the latter of which is more likely to experience neural cultural fit issues (De Leersnyder et al. 2011; Ward et al. 2004).

Limitations and future directions

One limitation of the current research is our definition of majority culture neural pat- terns. While the assumption that ECs hold majority culture patterns is more likely to hold in a North American university, such as seen in this study, as these universities are thought to follow predominantly independent/individualistic social orientations (Stephens et al. 2012), cultural fit is thought to be tied to the goals of the surround- ing culture (Li and Hamamura 2010; Searle and Ward 1990; Ward and Chang 1997). This suggests that individuals in cultures and contexts with different cultural neural patterns (e.g., more interdependent groups) would show a greater level of well-being when following their surrounding patterns. Future research should target other cultures and contexts to see if neural cultural fit translates to other settings. For example, would adherence to more context sensitive social neural patterns in Japan pre- dict more happiness for people living in Japan? Similarly, future research should investigate the boundary conditions of neural cultural fit to determine if it holds for other social tasks beyond emotion classification.

Another limitation is that while establishing the presence of neural cultural fit is important, it is also limited in its application, as it is not simple to measure and analyze ERPs. This would make it difficult to apply these findings as they stand in clinical settings where an individual might benefit from information on issues with neural cultural fit. Future research should attempt to find simpler measures that conceptually replicate these findings. For example, would it be possible to observe individual behaviors related to how people view social incongruence in clinical settings and infer similar cultural fit deficits without an ERP session? This is an important direction as health research has highlighted that while neuroscience measures offer important information on why we see differences in groups, simpler measures may yield similar information (e.g., Bruehl et al. 2009; McCrimmon et al. 2012). Find- ing simple measures is essential as they would be more cost-effective for potential interventions. As last limitations, we note that the self-report scale may not cover all aspects of well-being (and that well-being might be more complicated in sojourner populations), and such, replication is necessary. Similarly, we note the limitation in the current self-report scale, in the low reliabilities for social orientation that might be remedied with a more recent scale. In general, replication is important so that novel findings are properly established into theory.

Conclusions

In closing, this research provides the first evidence of neural cultural fit. Continuing recent trends in neuroscience, our findings show that neural patterns help explain processes involved in previously noted cultural patterns (Han et al. 2013; Han and Northoff 2009; Kitayama and Tompson 2010; Kitayama and Uskul 2011). In this case, we found that following majority culture social neural patterns is associated with higher reported well-being. This finding is important as it suggests that cultural fit depends not only on what we believe and how we act, but also how we think (e.g., neural patterns). As one of the great strengths of cultural neuroscience, we advocate for future process-oriented research using neuroscience to better understand the processes that explain culture (Masuda et al. 2018).

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Compliance with ethical standards

Conflict of interest The authors report no conflict of interest.

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