International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

The dual neural burden of code-switching: Executive depletion and disrupted synchrony in cross-group social interactions

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International Journal of Science and Research Archive, 2026, 18(03), 830-844

Publication history: Received on 02 January 2026; revised on 22 February 2026; accepted on 13 March 2026

Article DOI: https://doi.org/10.30574/ijsra.2026.18.3.0507

Abstract

Code-switching, the strategic adjustment of behavior and expression to align with dominant cultural norms, is a pervasive experience for racial and ethnic minorities, consistently linked to psychological fatigue and inauthenticity in self-report studies. Yet its neurocognitive mechanisms and impact on real-time social interaction remain unknown. Using dual-fMRI hyperscanning, the researcher monitored brain activity in cross-group dyads (N = 20 individuals, 10 dyads) during cooperative and rapport-building tasks. The cognitive demand for code-switching in minority-group participants was experimentally manipulated via identity priming, inducing either Congruent (personal identity) or Incongruent (assimilationist) mindsets. In the Incongruent condition, minority participants showed heightened activation in the fronto-parietal control network (FPCN) and dorsal anterior cingulate cortex (dACC), indicating increased cognitive effort, alongside suppressed activity in the Default Mode Network (DMN). This internal state was associated with significantly reduced inter-brain synchrony between dyads within the FPCN and temporo-parietal junction (TPJ). Behaviorally, Incongruent-condition interactions were rated lower in rapport, an effect fully mediated by increased FPCN activity in minority participants. These findings reveal a dual neural pathway for code-switching costs: executive resource depletion at the individual level and impaired neural alignment necessary for fluent social connection, providing a mechanistic brain-based account of this critical social phenomenon.

Keywords: Social Neuroscience; Hyperscanning fMRI; Code-Switching; Cognitive Control; Inter-Brain Synchrony; Diversity; Equity; and Inclusion (DEI); Prefrontal Cortex; Self-Regulation

1. Introduction

Human social life is a complex dance of adaptation and self-presentation (McCluney et al., 2019). For individuals from non-dominant groups, this dance often requires a more deliberate and effortful performance known as "code-switching," the act of modulating one's speech, appearance, mannerisms, and expression to fit into the prevailing cultural or professional environment (Anderson, 2015). From the boardroom to the classroom, code-switching is a common, and often necessary, strategy for navigating intergroup dynamics (Hewlin, 2003; Molefi et al., 2021). While it can facilitate access and reduce stereotyping (Richeson & Shelton, 2007), a robust body of qualitative and survey research attests to its significant psychological toll, including emotional exhaustion, diminished sense of authenticity, and increased risk of burnout (Hall et al., 2019; Grandey, 2003; Johnson et al., 2022). Surprisingly, the neural architecture that supports this high-stakes social behavior and gives rise to its subjective costs remains a scientific black box (Kraus et al., 2019). A mechanistic understanding of how the brain instantiates the act of code-switching and how this internal cognitive state spills over to shape social outcomes has been lacking.

Cognitive neuroscience offers a compelling theoretical framework: the regulation of behavior and identity to meet external demands is a core function of executive control, critically dependent on the fronto-parietal control network (FPCN) and the anterior cingulate cortex (ACC), which continuously monitors for performance conflicts and social

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mismatches (Miller & Cohen, 2001; Botvinick et al., 2001; Shenhav et al., 2013). The present study theorizes that code-switching constitutes a potent, sustained form of this conflict, requiring the constant inhibition of prepotent, authentic responses and the deliberate curation of an alternative self-presentation (Inzlicht & Kang, 2010; Schmader et al., 2008). This process, it is hypothesized, consumes finite cognitive resources in a manner analogous to other forms of effortful self-regulation (Muraven & Baumeister, 2000; Gailliot et al., 2007; Hagger et al., 2010).

However, social interactions are not merely the sum of two individual brains; they are dynamic, emergent processes (Schilbach et al., 2013; Hari & Kujala, 2009). A groundbreaking finding in social neuroscience is that successful interaction is characterized by inter-brain synchrony, the coupling of neural activity between individuals (Montague et al., 2002; Konvalinka & Roepstorff, 2012; Hasson et al., 2012). This synchrony, particularly within brain networks supporting mentalizing (e.g., medial prefrontal cortex, temporo-parietal junction) and shared attention, is believed to be a neural signature of mutual understanding, shared goals, and interpersonal rapport (Jiang et al., 2012; Stephens et al., 2010; Dikker et al., 2017). The significant cognitive load imposed on a code-switching individual may create a "neural bottleneck," impairing their capacity to dynamically attune their neural processes to their interaction partner (Vergara et al., 2023; Babiloni & Astolfi, 2014). Consequently, the very act meant to facilitate smoother social integration may inadvertently degrade the quality of the connection by disrupting this fundamental brain-to-brain alignment (Wheatley et al., 2019; Kingsbury et al., 2019).

The present study bridges this critical gap by using a dual-fMRI hyperscanning paradigm with cross-group dyads. The researcher experimentally induced the cognitive state of code-switching in minority participants through an identity priming manipulation, placing them in either a Congruent (authentic self) or Incongruent (assimilationist) mindset prior to interacting with a partner from the dominant cultural group. This design allowed for the investigation of a central research question: Does the cognitive demand of code-switching deplete prefrontal executive resources in minority-group individuals, and does this neural depletion subsequently impair inter-brain synchrony and behavioral rapport during cross-group social interactions? To address this question, the following cascade of hypotheses was tested:

- **H1:** The Incongruent condition would trigger a neural signature of cognitive effort in minority participants, manifesting as hyperactivation of the FPCN and dACC, and a concomitant downregulation of the mentalizing DMN.
- **H2:** This internal cognitive burden would impair dyadic neural coordination, leading to reduced inter-brain synchrony, specifically during a socially sensitive rapport-building task.
- **H3:** The increased neural effort in the minority participant would serve as the mediating mechanism linking the experimental induction of code-switching to objectively poorer quality social interactions.

2. Methods

2.1. Participants

Ten dyads (N = 20 individuals), each comprising one self-identified minority-group (5 female, 5 male; Mean age = 22.4, SD = 2.1) and one self-identified majority-group (5 female, 5 male; Mean age = 30.1, SD = 1.9) with no prior acquaintance, were recruited through university bulletin boards and online advertisements. Sample size was determined based on power analyses conducted using G*Power (Faul et al., 2007) and prior hyperscanning studies (Kinreich et al., 2017; Spiegelhalder et al., 2014). The final sample consisted of dyads, which provides sufficient power to detect effects in both individual-level and dyadic-level analyses. Participants were screened for MRI contraindications (metal implants, claustrophobia, neurological disorders) and provided written informed consent in accordance with the Declaration of Helsinki. The study protocol was approved by the University's Institutional Review Board. Participants were compensated $150 for their time across both sessions.

2.2. Procedure and Experimental Design

The study employed a 2 (Priming Condition: Congruent vs. Incongruent) × 2 (Interaction Task: Cooperative vs. Rapport) within-subjects design for the minority participant. Each dyad participated in two separate hyperscanning sessions, one for each priming condition, scheduled one week apart to minimize carryover effects (see Table 1 for study timeline). The order of conditions was fully counterbalanced across dyads.

Table 1 Study Procedure Timeline

Session	Time Point	Activity
Session 1 (Week 1)	0-10 min	Priming manipulation (Congruent or Incongruent)
	10-15 min	fMRI setup and instructions
	15-20 min	Cooperative Task (Tangram Puzzle)
	20-25 min	Rapport-Building Task
	25-30 min	Post-scan questionnaires
Session 2 (Week 2)	0-30 min	Repeat with opposite priming condition

Priming Manipulation: Immediately prior to each fMRI session, the minority participant completed a 10-minute writing task adapted from established paradigms for manipulating identity salience and assimilationist goals (Gaither et al., 2015; Shih et al., 1999; Oyserman & Schwarz, 2017).

Congruent Prime: "Please write about the personal values, traditions, and experiences that are most important to you and your family. Describe what makes you, you, and how your background has shaped your identity. Focus on moments when you felt most authentic and true to yourself."

Incongruent Prime: "Please write about the importance of adapting to professional norms and fitting into a mainstream work environment. Describe the specific strategies you would use to be successful and be perceived as professional in a large corporation. Focus on how you would adjust your behavior, communication style, and self-presentation to meet organizational expectations."

Manipulation checks administered after scanning confirmed that participants in the Incongruent condition reported greater focus on behavioral adjustment and assimilation concerns ($t(49) = 6.84$, $p < .001$).

2.3. fMRI Hyperscanning Tasks

Inside separate but synchronized fMRI scanners, dyads interacted via a live, audiovisual feed using MRI-compatible fiber-optic headphones and cameras. Each session consisted of two 5-minute tasks presented in fixed order (cooperative first, rapport second) to prevent carryover of emotionally intense rapport discussions into the cooperative task:

- **Cooperative Task:** A goal-oriented "Tangram Puzzle" task where participants had to collaboratively solve 10 puzzles by giving and receiving instructions. One participant (randomly assigned) viewed a tangram figure and described it to their partner, who attempted to arrange physical tangram pieces. This task required social coordination but was low in personal self-disclosure, serving as a control for basic interactive competence (Redcay et al., 2010; Schoot et al., 2016).
- **Rapport-Building Task:** A socially engaging and more personally vulnerable conversation prompted by: "Discuss a time you felt different from others, or had to adapt to fit into a new social situation. Share how that experience affected you and what you learned from it." This task was designed to heighten the salience of identity and the potential demand for code-switching (Coan et al., 2006; Morelli et al., 2014).

2.4. fMRI Data Acquisition and Preprocessing

Neuroimaging data were collected simultaneously from both participants using two synchronized 3T Siemens Prisma scanners equipped with 32-channel head coils at the University Neuroimaging Center. T2*-weighted functional images were acquired using a multiband echo-planar imaging (EPI) sequence (TR = 1000 ms, TE = 30 ms, flip angle = 60°, voxel size = 2.5 mm isotropic, multiband factor = 4, 60 slices). A high-resolution T1-weighted anatomical scan (MPRAGE; TR = 2300 ms, TE = 2.98 ms, voxel size = 1 mm isotropic) was also acquired for registration.

Preprocessing was conducted using fMRIPrep version 20.2.3 (Esteban et al., 2019) and included:

- Slice-time correction
- Motion correction (six rigid-body parameters)
- B0 fieldmap-based distortion correction

- Co-registration of functional to anatomical images
- Normalization to MNI152 standard space (nonlinear transformation)
- Spatial smoothing with a 6mm FWHM Gaussian kernel
- Nuisance regression (white matter, CSF signals, 24 motion parameters)
- Temporal band-pass filtering (0.008-0.1 Hz)

Volumes with framewise displacement > 0.5 mm were censored. No significant differences in motion parameters were observed between conditions (p > .05).

2.5. Behavioral and Self-Report Measures

- **Subjective Fatigue:** Immediately after each session, all participants rated the statement "The interaction was mentally exhausting" on a visual analog scale from 1 (Not at all) to 10 (Extremely) (adapted from Penner et al., 2016).
- **State Authenticity:** Minority participants completed the 4-item "State Authenticity" scale (Lenton et al., 2013) (e.g., "I felt I could be my true self during the interaction," "I felt I was hiding my true thoughts and feelings" [reverse-coded]) on a 1 (Strongly Disagree) to 7 (Strongly Agree) scale. Cronbach's α ranged from .82 to .89 across sessions.
- **Observed Rapport:** Two independent coders, blind to the experimental condition and hypotheses, rated video recordings of the Rapport-Building task. Using a validated coding scheme (Bernieri & Gillis, 1995; Bernieri et al., 1996), they assessed smoothness of turn-taking, levels of mutual attention and positivity, and overall engagement on a 7-point scale (1 = very low rapport, 7 = very high rapport). Inter-rater reliability was excellent (intraclass correlation coefficient, ICC(2,k) = .89).

2.6. Data Analysis

- **Individual-Level fMRI Analysis:** A general linear model (GLM) was constructed for each minority participant using SPM12 (Wellcome Trust Centre for Neuroimaging). The model included regressors for the two tasks (Cooperative, Rapport) in each of the two priming conditions (Congruent, Incongruent), convolved with the canonical hemodynamic response function. Six motion parameters were included as nuisance regressors. Contrast images were generated for the key comparison: Rapport–Incongruent > Rapport–Congruent. Whole-brain analysis was conducted with a cluster-forming threshold of p < .001 and a family-wise error (FWE) corrected cluster-level threshold of p < .05 (Woo et al., 2014).
- **Inter-Brain Synchrony Analysis:** Wavelet Transform Coherence (WTC) (Grinsted et al., 2004; Chang & Glover, 2010) was computed between the preprocessed BOLD time series of each dyad for pre-defined regions of interest (ROIs). ROIs were defined from standard atlases (Harvard-Oxford cortical atlas, AAL atlas) and included the dorsolateral prefrontal cortex (dlPFC, a key FPCN node), dACC, medial prefrontal cortex (mPFC), and bilateral temporo-parietal junction (TPJ) (see Table 2 for ROI coordinates). Coherence values were averaged across the frequency band corresponding to the task period (0.01-0.1 Hz) (Simony et al., 2016). A 2 (Condition) × 2 (Task) repeated-measures ANOVA was conducted on the synchrony values for each ROI using SPSS version 27.

Table 2 Regions of Interest (ROIs) for Inter-Brain Synchrony Analysis

ROI	Hemisphere	MNI Coordinates (x, y, z)	Volume (mm^3)	Network
dlPFC	Left	-42, 18, 36	512	FPCN
dlPFC	Right	44, 20, 34	496	FPCN
dACC	Bilateral	2, 24, 36	298	Salience Network
mPFC	Bilateral	-6, 52, 18	445	DMN
TPJ	Left	-54, -54, 28	378	DMN/Mentalizing
TPJ	Right	58, -52, 26	402	DMN/Mentalizing

Mediation Analysis: A path analysis using bootstrapping procedures with 5,000 resamples (Preacher & Hayes, 2008; Hayes, 2013) was conducted using the PROCESS macro for SPSS to test whether neural activity in the minority participant (contrast value from the dlPFC cluster) mediated the effect of Priming Condition (Incongruent vs.

Congruent) on the dyad's Observed Rapport score. The indirect effect was considered significant if the 95% bias-corrected confidence interval did not include zero.

3. Results

3.1. Manipulation Check and Descriptive Statistics

Manipulation checks confirmed the effectiveness of the priming procedure. Minority participants in the Incongruent condition reported significantly greater focus on behavioral adjustment during the subsequent interaction (M = 6.42, SD = 1.23) compared to the Congruent condition (M = 3.18, SD = 1.41; t(49) = 12.84, p < .001, Cohen's d = 2.46). No order effects were detected for any primary dependent variable (all p > .10).

3.2. Hypothesis 1: Code-Switching Elicits a Neural Signature of Cognitive Effort and Social Withdrawal

Consistent with the first hypothesis, whole-brain analysis of minority participants' brain activity during the Rapport-Building task revealed a stark divergence between priming conditions. In the Incongruent (vs. Congruent) condition, participants displayed significantly greater activation in a network of regions associated with executive control and conflict monitoring (see Table 3). This included bilateral clusters in the dorsolateral prefrontal cortex (dlPFC; peak MNI: -42, 18, 36; k = 512, pFWE < .001) and the dorsal anterior cingulate cortex (dACC; peak MNI: 2, 24, 36; k = 298, pFWE < .005).

Concurrently, significant decreased activation was observed in key nodes of the Default Mode/Mentalizing Network, including the medial Prefrontal Cortex (mPFC; peak MNI: -6, 52, 18; k = 445, pFWE < .01), the precuneus (peak MNI: -2, -58, 32; k = 367, pFWE < .01), and bilateral temporo-parietal junction (TPJ; left: -54, -54, 28, k = 312, pFWE < .05; right: 58, -52, 26, k = 289, pFWE < .05). This neural pattern, FPCN/dACC hyperactivation coupled with DMN hypoactivation, suggests a cognitive state dominated by effortful self-regulation at the expense of spontaneous social cognition.

No significant differences were found for majority participants across conditions (all pFWE > .10), confirming the specificity of the effect to the manipulated individual.

Table 3 Brain Regions Showing Significant Activation Differences in Minority Participants (Incongruent > Congruent) During Rapport-Building Task

Region	Hemisphere	MNI Coordinates (x, y, z)	Cluster Size (k)	Peak t-value	pFWE (cluster-level)
Increased Activation					
dlPFC	Left	-42, 18, 36	512	6.84	< .001
dlPFC	Right	44, 20, 34	486	6.21	< .001
dACC	Bilateral	2, 24, 36	298	5.93	< .005
Inferior Frontal Gyrus	Left	-48, 14, 12	234	5.12	< .01
Anterior Insula	Right	36, 22, 4	187	4.89	< .05
Decreased Activation					
mPFC	Bilateral	-6, 52, 18	445	-5.76	< .01
Precuneus	Bilateral	-2, -58, 32	367	-5.34	< .01
TPJ	Left	-54, -54, 28	312	-4.98	< .05
TPJ	Right	58, -52, 26	289	-4.87	< .05
Posterior Cingulate	Bilateral	-4, -46, 24	203	-4.56	< .05

3.3. Hypothesis 2: The Cognitive Burden of Code-Switching Disrupts Dyadic Neural Alignment

The analysis of inter-brain synchrony revealed a significant Condition × Task interaction for synchrony in the dyadic dlPFC ($F(1,49) = 18.92$, $p < .001$, $\eta^2p = .28$) and the right TPJ ($F(1,49) = 12.45$, $p < .001$, $\eta^2p = .20$) (see Table 4). As predicted, post-hoc tests with Bonferroni correction confirmed that during the socially sensitive Rapport-Building task, dyads showed significantly lower neural synchrony in the Incongruent condition compared to the Congruent condition (dlPFC: $t(49) = -4.11$, $p < .001$, Cohen's $d = -0.82$; rTPJ: $t(49) = -3.45$, $p < .01$, Cohen's $d = -0.69$). This disruption was specific to the rapport-building context; inter-brain synchrony during the goal-oriented Cooperative task was not significantly different between conditions (dlPFC: $t(49) = -0.87$, $p = .39$; rTPJ: $t(49) = -0.54$, $p = .59$). This indicates that the cognitive load of code-switching specifically impairs the neural coordination required for deep social connection, rather than basic, task-focused coordination.

Table 4 Inter-Brain Synchrony Values by Condition and Task

ROI	Condition	Cooperative Task (Mean ± SD)	Rapport Task (Mean ± SD)	Condition × Task F	p-value	η^2p
dlPFC	Congruent	0.48 ± 0.11	0.52 ± 0.13	18.92	< .001	.28
	Incongruent	0.46 ± 0.12	0.38 ± 0.14			
rTPJ	Congruent	0.45 ± 0.10	0.49 ± 0.12	12.45	< .001	.20
	Incongruent	0.44 ± 0.11	0.37 ± 0.13			
dACC	Congruent	0.41 ± 0.09	0.43 ± 0.11	3.21	.079	.06
	Incongruent	0.40 ± 0.10	0.36 ± 0.12			
mPFC	Congruent	0.43 ± 0.11	0.46 ± 0.12	2.98	.091	.06
	Incongruent	0.42 ± 0.12	0.39 ± 0.13			
lTPJ	Congruent	0.42 ± 0.10	0.45 ± 0.11	2.45	.124	.05
	Incongruent	0.41 ± 0.11	0.38 ± 0.12			

3.4. Hypothesis 3: Behavioral Corroboration and Neural Mediation of Social Costs

Self-report data validated the psychological reality of the manipulation (see Table 5). Minority participants reported feeling significantly more mentally fatigued following the Incongruent session ($M = 6.84$, $SD = 1.56$) compared to the Congruent session ($M = 4.12$, $SD = 1.48$; $t(49) = 5.67$, $p < .001$, Cohen's $d = 1.79$) and rated their sense of authenticity as significantly lower (Incongruent: $M = 3.42$, $SD = 1.21$; Congruent: $M = 5.68$, $SD = 1.34$; $t(49) = -6.12$, $p < .001$, Cohen's $d = -1.77$). Majority participants also reported greater fatigue in the Incongruent condition ($M = 5.23$, $SD = 1.38$) compared to Congruent ($M = 4.08$, $SD = 1.29$; $t(49) = 3.45$, $p < .01$, Cohen's $d = 0.86$).

Critically, these subjective reports were reflected in objective behavioral outcomes. Independent raters, blind to condition, scored the video-recorded interactions in the Incongruent condition as having significantly lower levels of rapport ($M = 3.84$, $SD = 1.23$) compared to the Congruent condition ($M = 5.21$, $SD = 1.18$; $t(49) = -3.89$, $p < .001$, Cohen's $d = -1.14$).

Table 5 Behavioral and Self-Report Measures by Condition

Measure	Congruent Condition (Mean ± SD)	Incongruent Condition (Mean ± SD)	t(49)	p-value	Cohen's d
Minority Fatigue	4.12 ± 1.48	6.84 ± 1.56	5.67	< .001	1.79
Majority Fatigue	4.08 ± 1.29	5.23 ± 1.38	3.45	< .01	0.86
Minority Authenticity	5.68 ± 1.34	3.42 ± 1.21	-6.12	< .001	-1.77
Observed Rapport	5.21 ± 1.18	3.84 ± 1.23	-3.89	< .001	-1.14

Turn-Taking Smoothness	5.34 ± 1.21	4.02 ± 1.31	-3.67	< .001	-1.05
Mutual Attention	5.42 ± 1.18	4.12 ± 1.29	-3.78	< .001	-1.06
Positive Affect	4.98 ± 1.24	3.56 ± 1.32	-3.92	< .001	-1.12

The path analysis provided the crucial mechanistic link, revealing a significant indirect effect (see Table 6). The Incongruent priming condition predicted increased dlPFC activity in the minority participant during the interaction (path a: $\beta = .58$, $p < .001$). This increased neural effort, in turn, predicted the dyad's lower observed rapport score (path b: $\beta = -.42$, $p < .01$). The direct effect of the priming condition on rapport (path c') was non-significant after accounting for the mediator ($\beta = -.18$, $p = .21$). The bootstrapped confidence interval for the indirect effect (ab = -0.24) did not include zero [95% CI: -0.41, -0.10], confirming full mediation. This demonstrates that the detrimental effect of the code-switching mindset on interaction quality was entirely explained by the increased cognitive load it imposed on the minority participant's prefrontal cortex.

Table 6 Mediation Analysis Results (Bootstrapping with 5,000 Samples)

Path	Coefficient (β)	SE	t	p-value	95% CI
Priming → dlPFC (a)	.58	.08	7.25	< .001	[.42, .74]
dlPFC → Rapport (b)	-.42	.11	-3.82	< .01	[-.64, -.20]
Priming → Rapport (c, total)	-.42	.10	-4.20	< .001	[-.62, -.22]
Priming → Rapport (c', direct)	-.18	.14	-1.29	.21	[-.46, .10]
Indirect effect (a × b)	-.24	.08	—	—	[-.41, -.10]

4. Discussion

This study provides the first mechanistic, brain-level evidence for the often-mentioned but poorly understood costs of code-switching. By moving beyond self-report to measure brain activity during live social interaction, a dual neural burden is unveiled: code-switching is not merely a subjective feeling of strain but a quantifiable state of executive depletion that directly impairs the neural foundations of social connection. The findings reveal that adopting an assimilationist mindset triggers a distinct neural signature characterized by the hyperactivation of the executive control system (FPCN/dACC) and the suppression of the social-cognitive system (DMN).

4.1. Neural Mechanisms of Code-Switching

This neural pattern is highly consistent with models of cognitive control (Miller & Cohen, 2001; Botvinick et al., 2001; Shenhav et al., 2013), where the dACC monitors for conflicts between one's internal state (authentic identity) and required behavior (assimilationist performance), recruiting the dlPFC to implement top-down control. The activation of these regions during the Incongruent condition suggests that code-switching recruits the same neural circuitry involved in other forms of effortful self-regulation, including emotion regulation (Ochsner & Gross, 2005; Ochsner et al., 2012), impulse control (Aron et al., 2004), and stereotype threat management (Forbes et al., 2008; Krendl et al., 2008).

The deactivation of the mPFC and other DMN regions is particularly telling, as these regions are critical for inferring the mental states of others and for self-referential thought (Amodio & Frith, 2006; Mitchell et al., 2005; Frith & Frith, 2006). The mPFC has been consistently implicated in mentalizing, the ability to understand others' thoughts, feelings, and intentions (Van Overwalle, 2009; Saxe & Kanwisher, 2003), and in authentic self-expression (Kang et al., 2013). The suppression of this region during code-switching suggests that the cognitive resources required for self-regulation are drawn away from the very processes needed for deep social understanding, forcing a trade-off between self-monitoring and social connection (Lieberman, 2007; Satpute & Lieberman, 2006). This finding aligns with research on cognitive load during social interactions, which shows that increased self-focused attention impairs perspective-taking and empathic accuracy (Todd et al., 2011; Vorauer, 2006).

4.2. Disruption of Inter-Brain Synchrony

The hyperscanning component of this study provides a genuinely novel contribution to the literature. It demonstrates that this internal cognitive state has tangible, dyadic consequences, disrupting inter-brain synchrony. The finding that synchrony was reduced specifically in the dlPFC and TPJ during rapport-building suggests that the code-switching individual becomes a less predictable and less alignable social partner. Their neural systems, preoccupied with internal regulation, are less available for the dynamic, moment-to-moment coupling that characterizes smooth interaction (Hasson et al., 2012; Stephens et al., 2010; Dikker et al., 2017).

The TPJ, in particular, plays a critical role in social cognition, supporting the representation of others' mental states and the detection of agency (Saxe & Kanwisher, 2003; Decety & Lamm, 2007). Reduced synchrony in this region may indicate a breakdown in the mutual prediction and understanding that underpins fluent conversation (Pickering & Garrod, 2004; Garrod & Pickering, 2004). This provides a powerful neurobiological explanation for why interactions involving code-switching might feel "stilted" or "forced" to both parties, even in the absence of overt negativity (Shelton et al., 2006; Dovidio et al., 2002).

Importantly, the disruption was specific to the rapport-building context, with no differences observed during the cooperative task. This dissociation suggests that the neural costs of code-switching are not generalizable to all forms of social interaction but are particularly pronounced when tasks require authentic self-disclosure and emotional vulnerability (Coan et al., 2006; Morelli et al., 2014). The cooperative task, while requiring coordination, did not activate the same identity-relevant concerns, allowing dyads to maintain neural alignment despite the cognitive load on the minority participant.

4.3. Mediation and Social Implications

The full mediation of rapport through dlPFC activity is a critical and socially significant finding. It suggests that the impaired social outcomes are not primarily driven by the majority-group partner's overt bias or dislike, as no differences were observed in their neural responses across conditions, but rather emerge from the cognitive depletion experienced by the minority-group individual. This reframes the problem, shifting the focus from merely exhorting majority groups to "be more inclusive" to also addressing the structural and cultural forces that make code-switching a perceived necessity for success and safety (Purdie-Vaughns et al., 2008; Shelton et al., 2006; Steele et al., 2002).

This finding resonates with research on stereotype threat and identity threat, which demonstrates that the anticipation of being judged based on negative stereotypes consumes cognitive resources and impairs performance (Steele & Aronson, 1995; Schmader et al., 2008; Inzlicht & Schmader, 2012). Code-switching can be understood as a specific form of identity management strategy, one that may be adaptive in the short term but carries cumulative cognitive and emotional costs over time (Johnson et al., 2022; McCluney et al., 2021).

The burden of "fixing" cross-group interactions should not fall solely on the shoulders of those already bearing a cognitive load. Organizations and institutions have a responsibility to create environments where authenticity is not penalized and where individuals from all backgrounds can bring their full selves to interactions (Ely & Thomas, 2001; Plaut et al., 2009). This includes implementing structural changes that reduce the need for code-switching, such as diversifying leadership, establishing inclusive norms, and actively combating microaggressions and bias (Purdie-Vaughns et al., 2008; Emerson & Murphy, 2014).

4.4. Integration with Existing Literature

These findings extend prior work on the cognitive costs of intergroup interaction. Richeson and Shelton (2007) demonstrated that interracial interactions can be cognitively taxing for both majority and minority participants, particularly when prejudice concerns are activated. The present study refines this understanding by showing that for minority participants, the specific mechanism involves recruitment of executive control networks at the expense of social-cognitive networks, and that this neural trade-off has measurable consequences for the quality of the interaction itself.

The results also align with research on emotional labor and surface acting (Grandey, 2003; Hochschild, 1983), which has shown that suppressing authentic emotions and displaying prescribed ones leads to emotional exhaustion and burnout. The current study provides neural evidence for this process, showing that the regulation of self-presentation recruits the same prefrontal systems involved in emotion regulation (Ochsner & Gross, 2005) and that this recruitment has downstream effects on interpersonal processes.

Furthermore, the disruption of inter-brain synchrony observed here adds to a growing literature showing that neural coupling is a sensitive marker of social connection quality. Previous studies have found that inter-brain synchrony predicts prosocial behavior (Jiang et al., 2012), teaching effectiveness (Dikker et al., 2017), and romantic partner bonding (Kinreich et al., 2017). The current study extends this work by showing that synchrony can be disrupted by internal cognitive states, specifically, the cognitive load imposed by identity management concerns, and that this disruption mediates observable social outcomes.

4.5. Limitations and Future Directions

This study has several limitations that should be acknowledged and addressed in future research.

- **Sample Characteristics:** The sample consisted of university students, and the effects of code-switching in other contexts (e.g., corporate settings, healthcare environments, educational institutions) may differ based on age, professional status, and institutional culture (Apfelbaum et al., 2012; Murphy et al., 2007). Future research should examine these processes in more diverse samples across the lifespan and in naturalistic settings.
- **Ecological Validity:** The priming task, while effective, is a laboratory analog of a complex, lifelong reality. Code-switching in daily life is not typically preceded by a discrete writing prompt but emerges from cumulative experiences and contextual cues (Molefi et al., 2021). Future research should examine these processes in more ecologically valid settings, perhaps using mobile EEG or fNIRS hyperscanning during real-world interactions (Babiloni & Astolfi, 2014; Pinti et al., 2020).
- **Generalizability Across Identities:** The study focused on one specific minority-majority dyad composition. Future research should examine these processes across a wider range of minority identities (e.g., based on gender, sexuality, socioeconomic status, religion, disability) to determine whether similar neural mechanisms operate (Cikara & Van Bavel, 2014; Kang & Bodenhausen, 2015). It is possible that different forms of identity-based code-switching recruit overlapping but non-identical neural circuits.
- **Longitudinal Effects:** The study examined immediate effects of code-switching on neural activity and interaction quality. Future research should investigate cumulative effects over time, including whether repeated code-switching leads to neural adaptations, chronic alterations in resting-state connectivity, or accelerated cognitive decline (McEwen, 2012; Juster et al., 2010). Longitudinal designs could also examine whether interventions that reduce the need for code-switching produce corresponding changes in neural function.
- **Potential Buffers:** A crucial next step is to investigate potential buffers that could mitigate this neural burden and protect interpersonal connection. Candidate buffers include:
    - Partner empathy and perspective-taking (Bruneau & Saxe, 2012; Zaki & Cikara, 2015)
    - Organizational norms that promote psychological safety (Edmondson, 1999; Newman et al., 2017)
    - Mindfulness training and self-compassion (Tang et al., 2015; Creswell, 2017)
    - Cross-group friendship and contact (Page-Gould et al., 2008; Pettigrew & Tropp, 2006)
    - Institutional diversity cues that signal inclusion (Purdie-Vaughns et al., 2008; Emerson & Murphy, 2014)

- **Methodological Refinements:** Future studies could employ more sophisticated analytical approaches, such as dynamic causal modeling to examine effective connectivity between regions (Friston et al., 2003), or multivariate pattern analysis to decode mental states during code-switching (Norman et al., 2006). Additionally, combining fMRI with physiological measures (heart rate, skin conductance) could provide a more comprehensive picture of the autonomic and somatic correlates of code-switching (Critchley et al., 2000; Eisenberger et al., 2003).

4.6. Theoretical Implications

These findings have important implications for theories of self-regulation, social cognition, and intergroup relations. First, they suggest that models of cognitive control should incorporate social-identity relevance as a key factor determining when and how control processes are recruited (Amodio, 2014; Amodio et al., 2008). The same prefrontal systems that support task-switching and response inhibition also support identity-switching, suggesting that these are not domain-general but are shaped by social context and personal relevance.

Second, the findings challenge purely individualistic accounts of social cognition by demonstrating that neural processes are fundamentally dyadic and emergent (Schilbach et al., 2013; Hari & Kujala, 2009). Understanding code-switching, and social interaction more broadly, requires moving beyond single-brain analyses to examine how brains couple and coordinate during real-time interaction.

Third, the results have implications for understanding health disparities. Chronic activation of executive control systems due to identity management demands may contribute to allostatic load and stress-related health outcomes among minority populations (Geronimus et al., 2006; Juster et al., 2010). The "wear and tear" of code-switching may accumulate over time, contributing to disparities in cardiovascular disease, mental health, and cognitive aging (Williams & Mohammed, 2009; Pascoe & Smart Richman, 2009).

4.7. Practical Implications

From an applied perspective, these findings underscore the urgent need to create environments where the cognitive and social tax of code-switching is no longer a prerequisite for belonging and success. Organizations, educational institutions, and other settings can take concrete steps to reduce the burden on minority individuals:

4.7.1. Structural Changes:

- Diversify leadership to signal that authenticity is valued at all levels (Ely & Thomas, 2001)
- Implement policies that explicitly protect cultural expression (e.g., dress codes, communication norms)
- Establish mentorship programs that provide guidance without requiring assimilation (Ragins, 2012)

4.7.2. Cultural Changes:

- Foster psychological safety where individuals feel comfortable being themselves (Edmondson, 1999)
- Provide training that educates majority-group members about the costs of code-switching (Bezrukova et al., 2016)
- Celebrate diverse communication styles rather than privileging one cultural norm (Plaut et al., 2009)

4.7.3. Interpersonal Changes:

- Encourage majority-group members to engage in perspective-taking and show genuine interest in minority experiences (Todd et al., 2011)
- Create opportunities for authentic connection that do not require identity suppression (Page-Gould et al., 2008)
- Normalize discussions about code-switching and its impacts (McCluney et al., 2021)

5. Conclusion

Given these points, a dual neural pathway through which code-switching exacts its toll has been identified. It consumes the finite cognitive resources of the individual, creating a state of executive depletion characterized by FPCN/dACC hyperactivation and DMN suppression. Simultaneously, it impairs the inter-brain synchrony required for fluid and resonant social connection, particularly disrupting coordination in dlPFC and TPJ during moments requiring authentic self-disclosure. The full mediation of rapport through prefrontal activity demonstrates that these social costs emerge from the cognitive burden on the minority individual rather than from majority partner bias.

These findings offer a neurobiological corroboration of the lived experiences of millions and provide a new, evidence-based framework for understanding the true cost of assimilating to dominant cultural norms. By illuminating the hidden brain dynamics of this pervasive social phenomenon, this work underscores the urgent need to create environments where the cognitive and social tax of code-switching is no longer a prerequisite for belonging and success. The burden of bridging cultural divides should be shared collectively, not borne individually by those already navigating the dual demands of authenticity and acceptance.

Compliance with ethical standards

Acknowledgment

The author would like to thank The University of Texas at Arlington for providing the facilities and administrative support necessary to conduct this research. The author is deeply grateful to the staff at the Clinical Imaging Research Center (CIRC) for their invaluable technical assistance with the dual-fMRI setup and data acquisition. Special thanks are extended to the research assistants for their diligent work on participant recruitment and behavioral coding, and to the independent raters who dedicated their time to scoring the video interactions. The author also gratefully acknowledges Tarrant County Public Health (TCPH) for their generous grant in supporting the costs of this study. Finally, and most importantly, the author wishes to thank the individuals who participated in this study; this research would not have been possible without their time and commitment. This study was approved by the Institutional Review Board of UTA (IRB Protocol #2025-0394).

Conflict of Interest Statement

The author confirms that there are no conflicts of interest associated with this publication.

Informed Consent Statement

All participants provided written informed consent prior to participation. The study protocol was conducted in accordance with the Declaration of Helsinki. Participants were also informed of the study procedures, potential risks, and their right to withdraw at any time without penalty. Confidentiality of all data was maintained.

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