

Decision Muscles? How Choosing More Food (Despite Incentives to Eat Less) Is Associated With the Brain's Cortical Thickness

Martin Reimann
University of Arizona

Can the mind be understood as a muscle? Both embodiment theorists and cognitive scientists have proposed that the architecture of the mind is flexible and adaptable. This proposition implies that cognitions can be shaped through repeated bodily actions and modal simulations, making them physically embodied at the brain level. To explore this notion, a measure of cortical thickness is extracted from anatomical brain scans to test whether cortical thickness is correlated with choice (here, in the domain of fast food). Results revealed that consumers' large-sized fast-food choices are significantly correlated with the cortical thickness of structures in the prefrontal cortex and that this association holds even for cases in which the participants were offered a possible monetary incentive to choose a smaller-sized portion. Body mass index, age, and sex were not correlated with cortical thickness or portion choice in the present data set. In summary, this work provides preliminary insights into the possible existence of a malleable, muscle-like brain, which would support the idea that cognitions are grounded in a plastic sensory system and subject to repeated bodily actions and modal simulations.

Keywords: cortical thickness, embodied cognition, modal simulation of food choice, consumer neuroscience, anatomical brain scans

In recent years, both cognitive psychologists and judgment and decision-making researchers have become increasingly interested in bodily actions (i.e., body movement and proprioception) and modal simulations (i.e., the reenactment of perceptual, motor, and introspective states) perceived through the sensory system and their effects on downstream cognitions such as judgment and choice (for a review, cf. Reimann et al., 2012). Researchers' interest has, in large parts, been sparked by the theory of grounded cognition (also referred to as embodied cognition), which proposed that bodily ac-

tions and modal simulations form the bases of cognition (Barsalou, 2008; Lakoff & Johnson, 1980). Indeed, perceptions of bodily actions can be manipulated by altering bodily movement and proprioception, and these perceptions have been shown to alter downstream cognitions, especially if they have metaphorical meaning in line with the cognition (Lakoff & Johnson, 1980; Lee & Schwarz, 2014). For example, washing one's hands has been found to "wipe one's slate clean" (Lee & Schwarz, 2010a, 2010b), firming one's muscles can firm one's willpower (Hung & Labroo, 2011), and standing outside a cardboard box seems to induce people to think outside the box and be more creative (Leung et al., 2012).

Interestingly, many effects in this area of inquiry rely on bodily actions that people *repeat frequently* (e.g., clenching fists, stretching fingers, or firming muscles; for a review, cf. Reimann et al., 2012) and/or modal simulations people *repeatedly reenact* (e.g., the systematic and pervasive use of metaphors; cf. Lakoff & Johnson, 1980; Lee & Schwarz, 2014). Therefore, it seems that (a) repeated bodily actions not only shape bodily muscles but also train

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Correspondence concerning this article should be addressed to Martin Reimann, Department of Marketing, Eller College of Management, University of Arizona, Tucson, AZ. E-mail: reimann@arizona.edu

muscles in people's minds and (b) repeated modal simulations mold cognitive *muscle mass*. Certainly, embodiment theorists have proposed a *flexible* cognitive architecture of perceptual, motor, and introspective states (Barsalou, 2008, 2010; Wilson, 2002), and neuroanatomists have suggested an *adaptable* architecture of the brain's cortex (Chen, He, Rosa-Neto, Germann, & Evans, 2008; Draganski et al., 2004; Hyde et al., 2009; Lazar et al., 2005; Maguire et al., 2000). If the cognitive architecture is truly flexible and adaptable, is it then possible that *embodied muscles* exist in people's minds that might help explain the striking results of earlier behavioral embodiment research? That is, could certain cognitions have been strengthened and shaped over time and thus become *physically embodied* through repeated bodily actions and modal simulations? In the judgment and decision-making context, could the multisensory and motor experiences of repeatedly engaging in certain cognitions (here, being more likely to choose fast-food meals over and over again) have possibly led to thicker cortices and, if yes, where exactly?

Herein, I will explore the possible associations between cortical thickness and judgment and decision-making. This work builds on the theory of grounded cognition, which proposed a flexible and adaptable cognitive architecture of perceptual, motor, and introspective states (Barsalou, 2008, 2010; Wilson, 2002). If "bodily states can cause cognitive states and be effects of them" (Barsalou, 2008, p. 618), then it is plausible that the repeated reenactment of perceptual, motor, and introspective states related to judgment and decision-making leads to thicker cortices over time. Indeed, there is a growing consensus in the cognitive sciences that the brain is plastic (for reviews, cf. Cotman & Berchtold, 2002; Kolb & Whishaw, 1998). Recent research in cognitive neuroscience has shown the brain to be a malleable structure, which supports my comparison of the mind to a muscle. For example, Ungerleider, Doyon, and Karni (2002) reported that learning a specific finger movement resulted in neuronal changes within the primary motor cortex in only a matter of weeks. Further, individuals who have long exercised spiritual meditation, compared with meditation novices, were found to have thicker cortices in certain brain areas (Grant, Courtemanche, Duerden, Duncan, & Rainville, 2010;

Lazar et al., 2005). Moreover, jugglers (vs. non-jugglers) showed changes in brain structure over time after training (Draganski et al., 2004). Along similar lines, musical training in early childhood has been found to shape structural brain development in just over a year (Hyde et al., 2009), and musical individuals who have practiced playing an instrument for a long time, compared with unmusical individuals, were found to have thicker cortices in certain brain areas (Hyde et al., 2007).

To date, it is unknown whether the idea of an *embodied muscle* generalizes to cognitions such as judgment and choice. Hence, this article attempts to close this knowledge gap by being the first to compare commonly and frequently reenacted judgments and choices with measurements of cortical thickness. Because people have for decades been observed to make many similar judgments and choices repeatedly and with high frequency (e.g., purchasing fast food, shopping for groceries, or getting gas; Grewal, Mehta, & Kardes, 2004; Hoyer, 1984; Scott, 1976), the consumption context offers an ideal opportunity to study structural brain plasticity because repeated judgments and choices in the same product categories can become automated, habitual performances in a way that mastering a musical instrument becomes automated and habitual (Ji & Wood, 2007; Neal, Wood, & Quinn, 2006).

In what will be reported in the following text, I acquired anatomical brain scans from a random sample of participants to determine each individual's cortical thickness across their entire brain by measuring the width of their gray matter (i.e., the accumulation of neurons and their synapses in millimeters). I focused on the context of fast-food choice, and I correlated consumers' percentage of large-portion fast-food choices with their cortical thickness. Particularly in the food context, consumers oftentimes choose larger-sized portions (e.g., a *super-sized* portion of French fries) over smaller-sized portions (e.g., a regular-sized portion of French fries), offered at almost identical prices, even if they are aware of impending overweight and health issues (Wansink & Cheney, 2005; Wansink & Kim, 2005; Wansink, Painter, & North, 2005). Building on this observation, one should expect to see greater cortical thickness *only* in brain areas associated with the specific cognitions that

are repeatedly performed, such as fast-food choices.

Method

Participants

In total, 42 individuals (25 female; $M_{\text{age}} = 21.31$ years, $SD = 2.32$) were recruited from the subject pool of an American university, provided written informed consent to a protocol approved by the institution's review board, were checked for medical eligibility, and underwent structural neuroimaging. The participants received a monetary compensation, a copy of their brain scan, and/or course credit.

Materials and Procedures

Neuroimaging data collection. The participants were asked to undergo structural neuroimaging. The high-resolution anatomical scan was performed in a 3T Siemens Magnetom scanner (Erlangen, Germany) fitted with a 12-channel matrix head coil and using a three-dimensional T1-weighted magnetization-prepared rapid gradient echo (Erlangen, Germany) sequence (echo time /repetition time /inversion time = 3.1/2,530/800 ms, flip angle = 10°, matrix = 256 × 256, field of view = 256 mm, and slice thickness = 1 mm without gap).

Behavioral data collection. The participants were also asked to make 12 binary choices between full-sized or half-sized food portions in a repeated-measures experiment (cf. Reimann, MacInnis, & Bechara, 2016). For example, the participants were asked to choose between a full-sized and a half-sized sub sandwich (see the full set of stimuli in Figure 1). Importantly, the participants were also informed that in a game of chance, they will win a certain amount of money (\$10, \$50, or \$100) if they choose the half-sized portion. Henceforth, this variable is abbreviated to *full-sized portion choice*. Food stimuli were presented in a pseudorandomized order on a screen, and the participants were asked to make their choices by clicking one of two buttons on a button box. The experiment was incentive compatible by way of having the participants expect to pay for their chosen food items and receive coupons for the same. The participants were informed that they would receive a coupon for their two most preferred food

items. The participants were further informed that they would be included in a raffle for the monetary premium amount they chose most often and that the cost of their two preferred food items (\$8 total) would be deducted from their monetary compensation. After the experiment, however, we waived the \$8 in food purchases and paid out the full monetary compensation to each participant. In summary, despite having the participants expect food coupons and expenses, this study was hypothetical. The number of full-sized portion choices (maximum = 12) was counted, and the percentage of full-sized portion choices for each condition was calculated. The participants were given a chance to win money for all half-sized portion options (either \$10, \$50, or \$100 in equal number of occurrences). Winning probabilities were deliberately kept undisclosed, so choices were made under uncertainty. The *total* number of full-sized portion choices was also counted, and the *total* percentage of full-sized portion choice was calculated. Besides providing behavioral choice responses, the participants also reported their height, weight, age, and sex. Body mass index (BMI) was calculated by using an established formula: [Weight in pounds/(Height in inches × height in inches)] × 703 (Center for Disease Control and Prevention, 2015). Note that this design could represent a measure of risk aversion (with the full-sized option always representing the *safe* option). However, previous research has also studied a condition in which no monetary incentive (\$0) was paired with the half-sized portion, which led to the majority of the participants considering the full-sized portion option (Reimann et al., 2016).

Anatomical Data Processing and Cortical Thickness Analysis

The cortical thickness analysis was performed on the basis of the anatomical scans that were obtained from the participants. The data processing and analysis procedures involved a number of different steps, which are summarized in what follows. In short, each participant's cortical thickness was calculated by identifying (a) the boundary between the white and gray matter and (b) the boundary between the gray matter and cerebrospinal fluid. The distance between these two boundaries yielded the cortical thickness at any given point across the

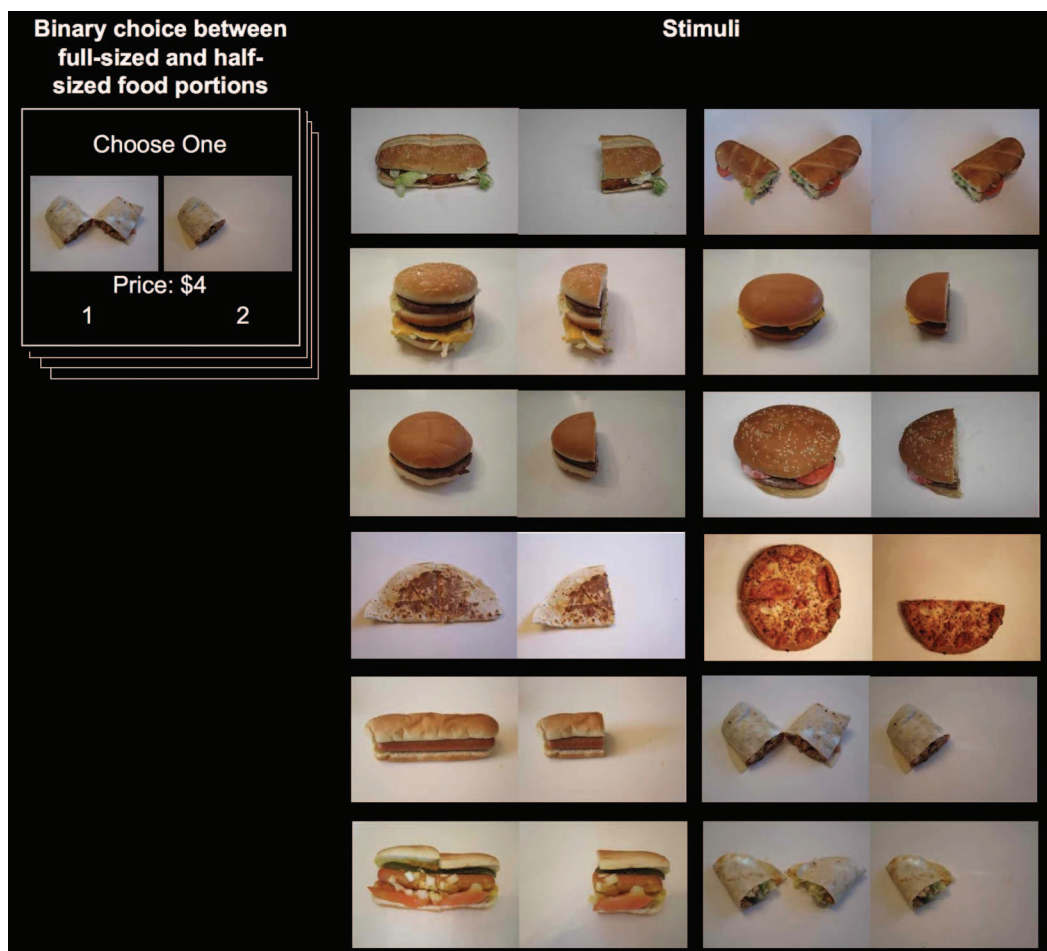


Figure 1. Food portions choice task and stimuli (cf. Reimann et al., 2016). See the online article for the color version of this figure.

cortex. Figure 2 provides an illustration of how each participant's cortical thickness (in millimeters) was extracted, starting with a simple anatomical image of each participant's brain.

Data import, preprocessing, and normalization. Data were analyzed in BrainVoyager QX 2.8 (Maastricht, The Netherlands). First, the anatomical raw data (Digital Imaging and Communications in Medicine format) of each subject were imported and converted into BrainVoyager's internal VMR data format. Second, data were corrected for spatial intensity inhomogeneity, using a standard correction method (Lieberman & Cunningham, 2009). This automatic procedure included a *brain peeling* of each subject's anatomical data set. Specifically,

this step analyzed the local intensity histogram in small volumes to define thresholds for an adaptive region-growing technique and results in the automatic labeling of voxels containing the white and gray matter of the brain. Third, each subject's anatomical file was transformed into anterior commissure and posterior commissure (AC-PC) and Talairach standard space, using a piecewise linear transformation.

Cortex segmentation. To perform a cortex-based data analysis, the gray/white matter boundary was segmented, using largely automatic segmentation routines (Vaughan et al., 2001). Following the correction of inhomogeneities of signal intensity across space as described earlier, the white/gray matter border

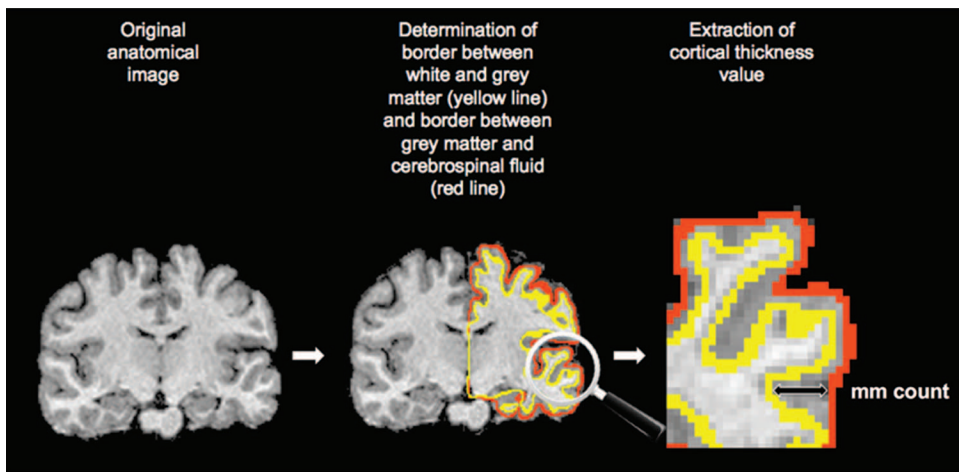


Figure 2. Steps to get cortical thickness values from an anatomical scan. See the online article for the color version of this figure.

was segmented with a region-growing method, using an analysis of intensity histograms. Morphological operations were used to smooth the borders of the segmented data and to separate the left from the right hemisphere. If necessary, manual corrections were made to obtain correct segmentation results. Each segmented hemisphere was finally submitted to a *bridge removal* algorithm, which ensures the creation of topologically correct mesh representations (Kriegeskorte & Goebel, 2001). The borders of the two resulting segmented subvolumes were tessellated to produce a surface reconstruction of the left and right hemispheres.

High-resolution intersubject cortex alignment. It has been shown for visual area V1 and the motor cortex that a cortical alignment approach substantially improves statistical group results by reducing anatomical variability (Kriegeskorte & Goebel, 2001). In BrainVoyager QX, a high-resolution, multiscale version of such a cortical mapping approach has been developed (Fischl, Sereno, & Dale, 1999), which automatically aligns brains using curvature information of the cortex. Because the curvature of the cortex reflects the gyral/sulcal folding patterns of the brain, this brain matching approach essentially aligns corresponding gyri and sulci across subjects' brains. Cortex-based alignment operates in several steps. First, each folded cortex representation is morphed into a spherical representation, which provides a pa-

rameterizable surface well suited for across-subject nonrigid alignment. The curvature information computed in the folded representation is preserved as a curvature map on the spherical representation. Second, the curvature information (folding pattern) is smoothed along the surface to provide spatially extended gradient information driving intercortex alignment, minimizing the mean squared differences between the curvature of a source and a target sphere. Third, an interactive alignment was performed, which follows a coarse-to-fine matching strategy developed by Goebel, Esposito, and Formisano (2006). Smaller structures, visible in the curvature maps with minimal smoothing, are aligned to a high degree but cannot be perfectly aligned due to anatomical differences between the subjects' brains. BrainVoyager offers two approaches to define a target brain for alignment. In the explicit target approach, one sphere is selected as a target to which all other spheres are subsequently aligned. The target sphere can be derived from one of the brains of the investigated group or from a special reference brain, such as the Montreal Neurological Institute (MNI) template brain. In the present case, the dynamic average of all subjects' cortices was used, yielding an average surface mesh across all 42 subjects.

Cortical thickness analysis. First, the normalized VMR data were interpolated to a higher

resolution version ($0.5 \times 0.5 \times 0.5$ mm), using a sinc interpolation. In this new data set, the ventricles and subcortical areas were filled, using a standard intensity value. Using an automatic detection approach, the cerebellum was removed. By applying a sigma filtering step, the tissue contrast of the data was enhanced. Next, the boundary between the gray and white matter was detected, using a gradient-based adaptive approach. On the basis of a dilation procedure, the border between the gray matter and cerebrospinal fluid was detected. The final result of the preparatory steps consists of a VMR representing only gray and white matter in two grayscale values. To calculate the cortical thickness in the whole cortex, Laplace equations were applied (Goebel et al., 2006). The volumetric cortical thickness values were sampled to standardized surface meshes of the separate hemispheres, using trilinear interpolation. The final cortical thickness surface maps for each subject were cortically aligned, using the results of the previous cortex-based alignment step.

Results

The extracted cortical thickness values across the cortex were correlated with the percentage of full-sized portion choices. Results revealed

that the thickness of two regions of the medial frontal gyrus (Brodmann area 10) is significantly correlated with the full-sized portion choice (at a global statistical threshold of $p < .008998$ and a cluster correction threshold of 25 mm^2): the *ventromedial prefrontal cortex* at and around Talairach coordinates $x = -11$, $y = 48$, and $z = 11$, and the *lateral prefrontal cortex* at and around $x = 28$, $y = 50$, and $z = 9$. Specifically, despite being offered substantial monetary incentives, such as possibly winning \$100, on choosing the half-sized portion, some participants still chose the full-sized portion, yielding the result that the percentages of the full-sized portion choice correlated with the cortical thickness in both the ventromedial prefrontal cortex ($r_{\text{cortical thickness} \times \% \text{ full-sized portion choice}} = .625, p < .001$) and the lateral prefrontal cortex ($r_{\text{cortical thickness} \times \% \text{ full-sized portion choice}} = .606, p < .001$). Figure 3 shows the correlational results for these two brain regions. Although cortical thickness did not correlate with the full-sized portion choice for the \$10 and \$50 conditions at the aforementioned statistical and cluster correction threshold (global $p < .001$ and 25 mm^2 cluster correction), second-level analysis revealed that the *total* percentage of full-sized portion choices correlated with the cortical thickness in the lateral prefrontal cortex

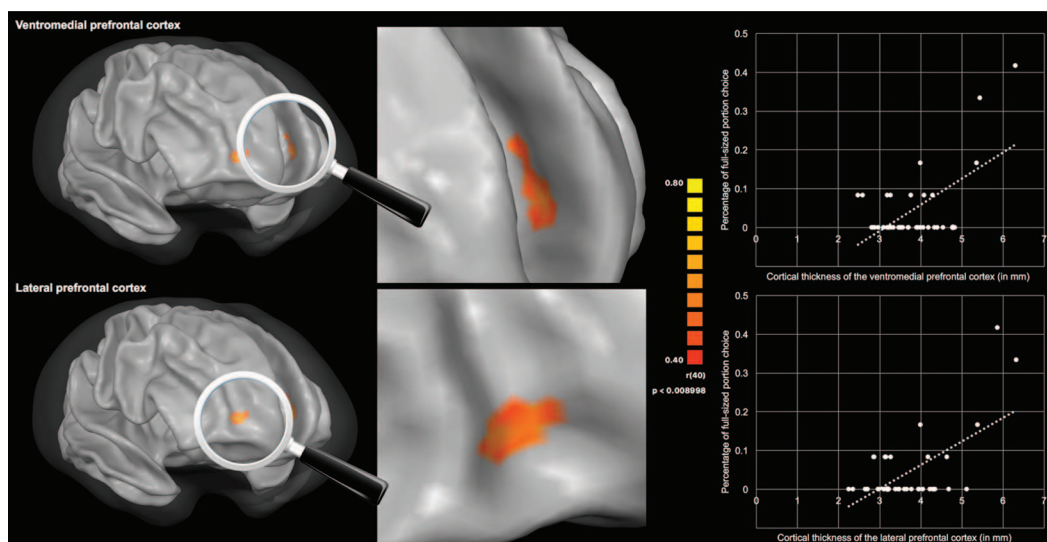


Figure 3. Full-sized portion choice correlates with the thickness of the prefrontal cortex (warmer colors indicate stronger correlations). See the online article for the color version of this figure.

($r_{\text{cortical thickness} \times \% \text{ full-sized portion choice}} = .395$, $p = .01$).

In support of these findings, results further revealed that the cortical thickness in these two regions did not significantly correlate with BMI ($r_{\text{average thickness vmPFC} \times \text{BMI}} = .022$, *ns* and $r_{\text{average thickness IPFC} \times \text{BMI}} = -.004$, *NS*), age ($r_{\text{average thickness vmPFC} \times \text{age}} = .120$, *ns*, and $r_{\text{average thickness IPFC} \times \text{age}} = -.177$, *ns*), or sex ($r_{\text{average thickness vmPFC} \times \text{female}} = -.139$, *ns*, and $r_{\text{average thickness IPFC} \times \text{female}} = .150$, *ns*), where IPFC = lateral prefrontal cortex and vmPFC = ventromedial prefrontal cortex. Moreover, further strengthening the findings, the percentage of the full-sized portion choice did not correlate with BMI ($r = -.065$, *ns*), age ($r = -.120$, *ns*), or sex ($r = .050$, *ns*).

Discussion

Core Insights

The present work aimed to answer the question of whether the decision-maker's mind can metaphorically be understood as a *muscle* that is built over time. Muscles in the body are bands and tissues that, if repeatedly contracted and relaxed, can be shaped and formed to build muscle mass. Herein, I make an analogy between bodily muscles and muscles in the decision-maker's mind to argue that the repeated reenactment of perceptual, motor, and introspective states related to judgment and choice might possibly have similar effects to repeatedly contracting and relaxing bodily muscles. Could a higher likelihood of choosing fast food on a repeated basis have led to a thicker cortex? Based on what is shown in this article, it is plausible that cognitions can be strengthened and shaped over time and thus become physically embodied. The article presents novel empirical evidence by showing that the thickness of the prefrontal areas—specifically, areas of the ventromedial prefrontal cortex and the lateral prefrontal cortex—is associated with the large-sized portion choice. Taken together, this article is the first to argue and show *physical* embodiment for a cognition that is central to people's everyday lives and of continued concern to many decision-making researchers.

Contributions to Extant Work, Opportunities for Future Research, and Limitations

This research contributes to and expands several different streams of work and provides opportunities for future inquiry. First, the present work contributes to the grounded cognition theory. Herein, I explored whether choice may possibly be embodied in a malleable, muscle-like brain at the very core of the central nervous system, which provides backing for the notion that cognitions are grounded in a plastic and dynamic sensory system and subject to repeated reenactment of perceptual, motor, and introspective states such as perceiving fast-food portions, coding and comparing their value, and anticipating their choice and consumption (Krishna, 2012; Schwarz, 2000, 2004). The results presented in this article provide preliminary backing for the idea that the mental activity of food choice, especially the full-sized portion choice, is physically grounded in the sensory system of the prefrontal cortex. This research, therefore, makes another step away from the amodal models of information processing (after which knowledge is assumed to solely reside in the semantic memory system, independent from the brain's modal systems for perception, action, and introspection) and toward models of grounded cognition that have proposed a more diversified cognitive architecture embodied in the sensory system (Barsalou, 2008). Importantly, the present work attenuates and clarifies the notion that "it is *unlikely* that the brain contains amodal symbols; if it does, they work together with modal representations to create cognition" (Barsalou, 2008, p. 618). According to the results reported here, information and knowledge of choice can be accumulated in the form of additional layers of neurons and synapses in the prefrontal cortex—a system of higher order decision-making that is different from the system that processes semantic memory (Martin & Chao, 2001) but is still part of the same brain. As a result of this new insight, future research is needed to study the interactions between choice and memory by conducting both behavioral and neuroimaging experiments.

Second, this work contributes to research on the role of *metaphors in judgment and choice*.

Previous work in this area has argued that bodily experiences could possibly activate metaphorically associated thoughts, goals, and feelings, which in turn construe and construct a decision (Lee & Schwarz, 2012). Given the new insights presented here, it is likely that the *bigger bang for your buck* metaphor ubiquitously used in everyday language leads to not only situational mental construction of single judgments and choices but also the *construction* of additional processing prowess at the brain level. Following this line of argumentation and following the idea that metaphors are systematically and pervasively used (Lakoff & Johnson, 1980), it becomes reasonable to assume that every time a metaphor is activated and reenacted, it adds to and strengthens the existing cognitive architecture. Because the present data set only captures the anatomical structures of participants at one single time point, future research is needed to study the role of metaphors in shaping our mind over time. If learning a finger movement results in neuronal changes in only a matter of weeks (Ungerleider et al., 2002), does the repeated use of or exposure to metaphors change our neuronal architecture in a relatively short amount of time?

Third, this research contributes to traditional work on *perceptual drivers of judgment and choice*. For example, in the food domain, plate size and plate color (van Ittersum & Wansink, 2012), container shape (Wansink & van Ittersum, 2003), and table diameter (Davis, Payne, & Bui, 2016) have all been shown to represent perceptual drivers of how much food we choose and consume. These perceptual drivers of choice are often determined by our social environment in the sense that our families and peers influence or even determine the judgments and choices we make as consumers (McFerran, Dahl, Fitzsimons, & Morales, 2010). In turn, our malleable cognitive architecture may thus have evolved (and may still be evolving) to support the specific circumstances of our social environments (Barsalou, 2008). As a consequence, our modal simulations (e.g., consumption-related value-seeking) may be determined by the cognitive architecture we currently have available. This idea has both positive and negative consequences, depending on different contingencies. No doubt, there are interesting contingencies (e.g., product category, goals, and perceived future consequences) relevant to the association

between consumer cognitions and cortical thickness that are worthy of further study.

Fourth, the results offered herein also expand research that is concerned with the *neurophysiological sources of choice*. Although previous work on choice and the prefrontal cortex has associated brain function (i.e., blood flow) with judgment and choice (for reviews, cf. Levy & Glimcher, 2012; O'Doherty, 2004; Rangel, Camerer, & Montague, 2008; Wallis, 2007), the present work provides evidence for a possible *hard-wiring* of choice shown in the accumulation of gray matter in the prefrontal cortex. The choice-related signal of the prefrontal signal has its roots in the brain's dopamine system. Dopamine is an organic chemical that functions as a neurotransmitter or, in other words, as a chemical that is discharged by nerve cells to communicate signals to other nerve cells (cf. Seeman, 2010 for a history of dopamine research). Dopamine is released deep down in the brainstem upon perception of any rewarding stimulus such as food or money (D'Ardenne, McClure, Nystrom, & Cohen, 2008) and then projected to several different areas of the brain, including the striatum in the midbrain and the frontal lobe (Schultz, 1986, 1998, 2007; Wise & Bozarth, 1987). Although the occurrence of dopamine in the striatum is associated with the actual reception and experience of rewarding stimuli such as money (Knutson, Adams, Fong, & Hommer, 2001), chocolate (Knutson, Rick, Wimmer, Prelec, & Loewenstein, 2007), and aesthetically designed products (Reimann, Zaichkowsky, Neuhaus, Bender, & Weber, 2010), the occurrence of dopamine in the prefrontal cortex is associated with cognitive functions related to the valuation of rewards (Carr, O'Donnell, Card, & Sesack, 1999; Volkow, Wang, & Baler, 2011; Wise, 1978, 2002). Building on the finding that the frontal cortex—especially the ventromedial prefrontal cortex—processes higher order cognitions such as weighing the future consequences of one's choices (Bechara, Damasio, Tranel, & Anderson, 1998; Bechara, Damasio, Tranel, & Damasio, 1997, 2005), there is now growing agreement that the prefrontal cortex is a critical system in the task of coding choice (Levy & Glimcher, 2012; O'Doherty, 2004; Plassmann, O'Doherty, & Rangel, 2007; Rangel et al., 2008; Wallis, 2007).

Fifth, this work also expands *research in consumer neuroscience and decision neurosci-*

ence from a methodological point of view. This article is the first in judgment and decision-making research to extract a measure of cortical thickness from anatomical brain scans to test whether cortical thickness is associated with judgment and choice. The measurement of cortical thickness adds a novel method to research in consumer neuroscience and decision neuroscience, which has so far focused on *functional* neuroimaging (Craig, Loureiro, Wood, & Vendemia, 2012; Hedgcock & Rao, 2009; Yoon, Gutches, Feinberg, & Polk, 2006) but not investigated a core *anatomical* feature: cortical thickness. Although functional neuroimaging only assesses situational brain activation while engaging in a behavioral task, anatomical neuroimaging provides insight into the “hardware” of the brain (Fischl et al., 1999; Reimann, Schilke, Weber, Neuhaus, & Zaichkowsky, 2011). Because functional neuroimaging typically requires investigators to also accumulate anatomical brain scans, besides the functional brain scans, to compare function with anatomy, neuroimaging researchers already possess data with potentially many new insights. The method description herein offers a way to determine cortical thickness from anatomical brain scans, which should enable future researchers to harvest their existing data by associating with and comparing cortical thickness measures with measures of self-report and behavior.

Sixth, this work has an important limitation, which future research could confront. The present work is limited (a) in its cross-sectional design, as opposed to a longitudinal design in which participants engage in a certain training task over time, and (b) in the lack of a control group that may not perform fast-food choices on a regular basis. To address this limitation, future work could follow the approach of Draganski et al. (2004) and induce changes in the gray matter through behavioral training. This approach could more directly test the question of whether a certain choice-related training can efficiently modulate changes of certain brain structures. Alternatively, future work could attempt to compare participants with certain characteristics (e.g., regular fast-food consumers) with a “control” group (e.g., vegetarians) to examine how such characteristics shape the size of brain regions (while also controlling for BMI). The work of Maguire et al. (2000) followed this approach by comparing London taxi drivers

with control subjects who did not drive taxis and showing a significantly larger posterior hippocampi of taxi drivers (vs. control). These two approaches could possibly more directly test the “muscle” metaphor brought forward in this article. Nonetheless, the present work is a first step toward a better understanding of choice possibly being “embodied” in the cortex’s thickness.

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