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EXPLORING THE BODY SPECIFICITY HYPOTHESIS IN ECOLOGICAL ENVIRONMENTS

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Abstract

The Body-Specificity Hypothesis (BSH) proposes that the space toward the dominant hand is perceived with a positive valence due to the motor fluency associated with that hand. In contrast, the space toward the non-dominant hand is perceived with a negative valence.

Experimental studies aligned with this theory have demonstrated connections between affective valence and hand dominance, indicating a positive association with the dominant hand and a negative association with the non-dominant hand. This effect is known as the hand-valence association where the dominant hand exhibits faster responses to positive stimuli, and the non-dominant hand shows quicker responses to negative stimuli. This effect is commonly compared to the space-valence association, where these associations (dominant hand positive; non-dominant hand negative) also apply to the space surrounding the dominant and non-dominant hand.

This work aimed to build upon existing evidence related to the BSH, specifically confirming whether associations tied to the body, such as space-valence associations, hand-valence associations, and valence reinforcement effects (i.e. stimuli are evaluated as more positive or more negative depending on the fluency and the congruency of lateral movement of hands) would be evident in a valence judgment task performed through a swipe gesture on the touchscreen of a tablet.

Our primary objective was to investigate body-specific associations in environments that replicate real-world situations and ascertain whether these associations extend to everyday "digital" gestures, such as the swipe gesture. This specific gesture has become prevalent in our interactions with digital touchscreen interfaces, particularly on smaller to medium-sized devices, and has acquired distinct connotations over time. Typically, swiping right is associated with positive valence, while swiping left is often linked with negative valence.

In Experiments I and II, we presented 28 images (14 negative and 14 positive, previously validated in a manipulation check experiment with 60 participants) on a mobile touchscreen device to 30 right-handed (Experiment I) and 30 left-handed participants (Experiment II). We asked them to make valence judgments (one hand at time, dominant and non-dominant, in two separate sessions) in both congruent (i.e., swipe toward the dominant space for positive images, swipe toward the non-dominant space for negative images) and incongruent (i.e., swipe toward the dominant space for negative images, swipe toward the non-dominant space for positive images) tasks. In both experimental conditions, following the valence judgment task, the presented picture vanished, prompting participants to assess the intensity of their positive or negative response using a vertically oriented Likert scale, ranging from 1= not very positive/negative to 9= very positive/negative.

Results highlighted that right-handers (Experiment I) were faster (p =.01) in the congruent condition compared to the incongruent condition, addressing space-valence associations, and supporting the extracorporeal origin of BSH.

Intriguingly, right-handers were faster ($p < .001$) in swiping for negative images with the non-dominant hand (i.e., hand-compatibility effect), addressing the intracorporeal origin of BSH.

This hand compatibility effect did not manifest in left-handed participants, (Experiment II) who were faster ($p < .001$) in the congruent condition compared to the incongruent one, but only when using the non-dominant hand. This supports the idea that, for left-handed individuals, the choice of the responding hand is crucial, indicating greater adaptability in interactions with the environment when employing their dominant hand. This adaptability occurs only at an implicit level.

Left-handed participants, unlike their right-handed counterparts, showed significant differences in valence evaluation levels (i.e., valence reinforcement effects), with more positive and negative evaluations in the congruent condition compared to the incongruent one independently of the hands involved in the swipe gesture ($p = .01$).

Experiment III, conducted as a follow-up to Experiment I, delves into the debate surrounding extra vs intracorporeal origin of the BSH. The specific aim was to investigate and determine whether body-specific associations should be categorized as originating within the body (i.e., intracorporeal) or extending beyond the body (i.e., extracorporeal). This analysis also considers the shifts observed between intra- and extracorporeal effects in Experiment I. For this purpose, 30 right-handed participants were instructed to perform the swipe movement with both the dominant and non-dominant hand within the same experimental session. The materials and stimuli mirrored those used in Experiment I, with the exception of the relative position of the two hands. In the congruent condition, the hands were parallel (swipe right for positive, swipe left for negative), while in the incongruent condition (swipe right for negative, swipe left for positive), they were crossed. This design allowed us to disentangle space-against-hands effects.

Results highlighted that participants were faster in the congruent condition compared with the incongruent ($p = .003$), addressing the extracorporeal origin of BSH. However, a faster response to negative images with the non-dominant left hand (i.e., hand compatibility effects) ($p < .001$) was observed, supporting the intracorporeal origin of BSH. The findings from Experiment III suggest that the BSH can manifest as both an intracorporeal and extracorporeal effect simultaneously, even in cases where incongruent information is conveyed by both hands and side.

Experiment IV investigated the influence of spatial location (center vs right vs left) on the valence evaluation of 36 neutral images sourced from the OASIS database, involving both 15 right-handed and 15 left-handed individuals.

The aim of this experiment was to fill a gap in the existing literature as there is currently no evidence regarding the evaluation of neutral images based on the spatial positioning of stimuli.

Experiment IV comprised two sessions with a 3-week interval. In the first session, participants engaged in a valence evaluation task with 36 images presented randomly at the center of the screen. Each participant viewed a single image for 4 seconds, followed by a prompt on the screen to judge the image's positivity or negativity. Responses were recorded on a vertically oriented 9-point Likert scale, ranging from 1=poorly positive/negative to 9=very positive/negative.

After a 3-week interval, participants repeated the procedure in the second session without receiving additional information. The second session closely replicated the first, with the primary difference being the alternating placement of images initially presented at the center, now positioned on both the right and left sides of the screen.

The results showed that right-handed participants tended to give more negative evaluations to images positioned on the left compared to those in the center (p = .007). In contrast, left-handed individuals did not exhibit statistically significant differences in valence evaluations across various stimuli (p = .85). In addition, an interaction effect between handedness and location (p = .02) indicated that left-handers tended to provide more positive evaluations to images on the left side compared to right-handers.

Collectively, the findings from Experiments I, II, and III challenge the conventional separation between hand-valence and space-valence associations in scientific literature. The data suggest that examining both associations concurrently provides a more comprehensive understanding of the phenomenon. Moreover, intriguing results were observed in both right-handed and left-handed individuals, particularly when considering the non-dominant hand, which is theoretically less influenced by continuous interactions with digital devices.

Finally, Experiment IV revealed groundbreaking findings, demonstrating a valence reinforcement effect associated with image location without the involvement of lateral hand movements or motor feedback. Moreover, this experiment provided pioneering evidence, highlighting a divergence in valence evaluations between right-handed and left-handed individuals, specifically tied to the location of images.

In conclusion, the four experimental studies presented in this thesis contribute fresh insights to the existing literature on embodied cognition, highlighting the intricate interplay between handedness, space-valence associations, hand-valence associations, and valence reinforcement effects. Additionally, these studies offer practical perspectives in real-world scenarios, emphasizing ecological settings.

Furthermore, the thesis proposes that in natural settings, the BSH exhibits vulnerability to the prevalent digital language, specifically conveyed through the swipe gesture, incorporating inherent connotations. This susceptibility manifests in various ways among individuals, distinctly differentiating between right-handers and left-handers.

General Introduction

This thesis is framed within the general theoretical framework of Embodied Cognition (EC, Barsalou, 1999, 2003, 2008). In particular, I will delve into the Body Specificity Hypothesis (BSH, Casasanto, 2009), which will be detailed in Chapter 3. However, before delving into BSH, it is worthwhile to provide a broader introduction to EC.

EC is a theoretical framework within cognitive science that posits our cognitive processes are deeply rooted in our physical interactions with the environment (Barsalou, 1999).

This is evident in the understanding of perception- and action-related language, where words like "red," "loud," "pick," or "kick" activate sensorimotor representations (Fischer & Zwaan, 2008; Pecher et al., 2003; Pulvermüller, 2005). Additionally, neuroscientific evidence (Hauk et al., 2004) supports this perspective.

Unlike traditional cognitive theories, which often focus solely on the brain as the seat of cognition, EC emphasizes the integral role of the entire body in shaping our perceptions, thoughts, and actions (Varela et al., 1991). This perspective contends that the mind is not isolated from the body but rather intricately connected, and that our sensory experiences, gestures, and movements play a crucial role in shaping our understanding of the world. For example, it is habitual for individuals to employ gestures while engaged in verbal discourse. This practice not only serves to enhance both interpersonal communication and the processing of language but also possesses the capacity to reciprocally impact the cognitive processes of the gesturer (Beilock & Goldin-Meadow, 2010).

In contrast to computational cognitive science, which has easily identifiable commitments, EC is more appropriately described as a research program lacking clear defining features. The central tenet of EC posits that computational cognitive science has overlooked the crucial role of the body in cognitive processing, necessitating a significant re-conceptualization of the nature of cognition and its investigative methods. Various researchers interpret the significance of the body in cognition differently, leading to a wide range of perspectives within the field. Despite this broad diversity, it is possible to distill three major themes that serve as focal points for discussions on EC: *Conceptualization, Replacement,* and *Constitution* (Shapiro & Stolz, 2019).

According to the *Conceptualization* perspective, the concepts through which organisms recognize, categorize objects, reason, draw inferences, and communicate are heavily influenced by the body. This idea has been substantiated through various lines of argumentation. For example, Lakoff and Johnson (1980) suggest that all concepts, including less-basic ones, bear the imprint of the body, with characteristics trickling up from basic to more abstract concepts. The concept of "up," for instance, is considered basic and emerges from the body's erect orientation.

Advocates for the full *Replacement* of traditional cognitive science often draw inspiration from ecological psychology (e.g., Gibson, 1966). However, on a less radical front, there are arguments supporting the abandonment of certain elements of traditional cognitive science. Some propose relinquishing the notion that cognition is solely a product of rule-guided inference while still holding onto other aspects, such as the idea that cognition involves representational states (Chemero, 2009; Hutto & Myin, 2013).

Finally, according to the *Constitution* perspective, in the realm of computational cognitive science, the constituents of a cognitive system are regarded as brain processes engaged in computations. The causes of cognition, according to this perspective, stem from factors like environmental stimuli influencing the body. Contrarily, many proponents of EC argue against this notion, asserting that the constituents of cognition extend beyond the brain to encompass the body and the environment. As an example, it was suggested that the process of writing, is not always about fully formed thoughts being transcribed onto paper. Instead, the paper serves as a medium through which, facilitated by a coupled neural-scribbling-reading unfolding, individuals can explore ways of thinking that might otherwise be inaccessible (Clark, 2008).

In this perspective, the paper, along with the acts of reading and writing, constitutes integral parts of the cognitive process, no less significant than neural processes, owing to the continuous interactions among all these elements.

These foundational themes, introduced in this general introduction, serve as guiding threads weaving through the fabric of our investigation. By revisiting and unraveling these concepts, the aim is to illuminate the multifaceted nature of EC. The subsequent chapters will unfold as a journey into the rich tapestry of theories, evidence, and discussions surrounding the embodied mind, addressing these thematic dimensions with greater precision and depth. Specifically, Chapter 1 will scrutinize the philosophies (and theories) underpinning EC, while Chapter 2 will delve into EC dimensions. Chapter 3 will examine the Body Specificity Hypothesis (BSH), unraveling its implications within the broader context of EC. Finally, Chapters 4, 5, 6,7 and 8 will investigate the BSH and its manifestations across four empirical studies.

PART I: Theoretical foundations of embodied cognition

1. Philosophies and Theories Underpinning Embodied Cognition

The EC paradigm has its roots in two distinct philosophical traditions, drawing from a synthesis of continental and pragmatist philosophies: naturalism and phenomenology (Johnson, 2006, 2007). Naturalism contends that all entities in the world, including both body and mind, naturally originate rather than as non-material entities (Aikin, 2006; Horst, 2002). Consequently, it asserts that explanations should be causally linked to the tangible, natural world (Aikin, 2006; Johnson, 2006). Naturalism posits cognition as emerging from the interplay between the organism and its environment (Johnson & Rohrer, 2007).

In particular, philosophers Johnson and Rohrer (2006, 2007) developed the naturalistic tenets of EC, drawing from the works of William James, a philosopher, psychologist, and physician, as well as John Dewey, a philosopher, psychologist, and education activist (from works between 1925-1953; in 1981, 1991). Both James and Dewey underscore the role of bodily adaptations in cognition. James critiqued "rational psychology" for failing to account for cognitive activities without reference to the world they pertain to. Thus, he proposed that higher cognitive functions result from interactions with the world, predominantly involving the body and environment (James, 1892). Dewey (1981) extended this concept, suggesting that higher cognitions stem from organic activities like feeling, perception, object manipulation, and bodily movement. In sum, both James and Dewey elevated body and world as essential components of cognition from an evolutionary perspective.

From to this perspective, cognition must be understood in connection to the body's engagement with the world (Merleau-Ponty, 1962). In this vein, Maurice Merleau-Ponty, a French philosopher and psychologist, provided a prominent phenomenological account supporting EC through the "lived-body" concept.

Merleau-Ponty considered the body as "lived-through" and "subjective" in cognitive experience, distinct from being a "passive" and "objective" vessel through which the mind operates.

Merleau-Ponty thus underscores body and world as vital constituents of cognition from a phenomenological standpoint.

Although phenomenological and naturalistic explanations were traditionally seen as incompatible, they can complement each other (Aikin, 2006; Borrett et al., 2000; Gallagher & Zahavi, 2008).

In this vein, the ecological theory (Gibson, 1979) integrated both phenomenological and naturalistic perspectives. This theory posited that perception is direct and that the environment carries meaningful information, aligning with Dewey's naturalism and Merleau-Ponty's phenomenology. Specifically, Gibson's ecological theory (1979) proposed a deep interrelation between perception and action, closely tied to the organism's direct interaction with its environment. This paradigm challenged the prevailing notion that perception was a passive process solely reliant on sensory input.

Interestingly, during the 1960s, when the representational and computational theory of mind was developing, Gibson formulated his theory of perception. Due to the unconventional nature of his ideas, he received little attention from the cognitive science community. However, with the rise of EC and the crisis in classical cognitive science, Gibson's ecological psychology gained recognition. Gibson's theory rests on three assumptions: (1) perception is direct, meaning it doesn't necessitate mental representations; (2) perception serves to guide action, rather than collecting irrelevant information; (3) if perception is direct and serves the function of action, then the environment must provide sufficient information to guide action. The third point led to the formulation of the well-known concept of "affordance", a pivotal concept in EC.

According to this concept, perception doesn't duplicate the external world, creating an internal replica, but rather extracts from the environment a set of information that is functional for the individual's action. This information doesn't correspond to simple first-order psychophysical variables (such as direction, brightness, spatial frequency, wavelength, or duration) but rather to higher-order relational characteristics.

In essence, the amalgamation of Gibson's ecological theory (1979) with EC signified a confluence of perspectives that transcends entrenched dichotomies (Chemero, 2009). At its core, this convergence rejects the Cartesian dualism that artificially severs mind from body. This convergence propels cognitive science towards a more comprehensive grasp of how the mind intricately interlaces with the environment, with the body serving as the conduit through which perception, action, and cognition harmonize. This amalgamation not only enriches the theoretical framework itself but also unfurls novel avenues for empirical inquiry, promising profound insights into the essence of cognition itself.

In other words, EC extended Gibson's ecological insights, accentuating the profound interdependence of cognition and bodily experiences (Chemero, 2009). It posits that cognitive processes are intricately interwoven with bodily experiences, encompassing not only sensory inputs but also motor actions, emotions, and bodily sensations. This broader perspective acknowledges the pivotal role of the body as an active agent in shaping cognition.

Both paradigms converge in their dismissal of the conventional view that cognition is confined to neural processes within the brain. They advocate for a more holistic comprehension of cognition, one that acknowledges the ecological setting in which it unfolds. This shared emphasis on the ecological context as a critical determinant of cognitive processes underscores their inherent alignment.

Furthermore, as mentioned earlier, EC draws its emphasis on the motor aspect from Gibson's ecological psychology (Gibson, 1979) but also from American pragmatism, collectively referred to as "American naturalism" (Ryle, 1949).

American pragmatism has notably contributed by emphasizing that every mental act must be examined with regard to the role it plays for a specific agent. According to pragmatists, concepts are not mere representations of objects, but instructions for interacting with those objects, geared towards action.

In line with this perspective the concept of a "horse" doesn't simply represent the animal, but encompasses a complex set of practical knowledge associated with horses, including ways to interact with them (Mead, 1934). This concept encompasses actions like approaching a horse, which, in someone familiar with these animals, triggers a series of potential acts, like choosing the correct side and preparing to mount. Additionally, it evokes other practical knowledge, such as the fact that a horse needs to eat, has economic value, an owner, and more. All these characteristics are implicitly embedded in the idea of a horse. This network of knowledge linked to horses is extensive and deeply rooted in the cerebral centers involved in preparing various acts.

Particularly, according to Mead (1934), if we were to seek the ideal character of a horse in the central nervous system, we would find it in all the different parts of the initiated acts. Each of these acts is associated with other processes where a horse is involved, regardless of the specific act. In this way, at the inception of an act, we can find the characteristics attributed to a "horse" as an idea or concept. This perspective significantly differs from an a-modal representation where animal-related concepts, irrespective of the specific relationships a subject has with that particular animal, are categorized into specific areas of higher-order visual regions, as proposed by the "domain-specificity hypotheses"(Mahon & Caramazza, 2008).

Moreover, it is evident that the pragmatist account, as summarized earlier, not only deviates from an a-modal description but also from a perception-based representation. This is because it places a greater emphasis on the motor and, indeed, pragmatic aspect. According to the pragmatists, the sensory impression exists solely to initiate the central process of reflection, which in turn only exists to stimulate the final act (James, 1956). This radically contradicts the phenomenological assertion of the primacy of perception, where the voluntary aspect of our nature dominates both the intellectual and sensitive aspects. In simpler terms, perception and thinking exist solely by virtue of behavior.

However, in the realm of cognitive sciences, particularly in Italy, the uptake of American pragmatism has been minimal and has wielded little influence, which stands in contrast to the reception of phenomenology (Caruana & Borghi, 2013). Conversely, the emphasis on the motor aspect, rooted in the ecological tradition, has become crucial for interpreting significant major neuroscientific breakthroughs.

A notable illustration of this is the identification of mirror neurons (Rizzolatti & Craighero, 2004; Rizzolatti & Fadiga, 1998). Mirror neurons are premotor neurons that activate during the grasping of objects, and their form leads to specific hand configurations. Each neuron is primarily influenced by the grip of a specific object, likely encoding the most optimal hand configuration for interaction.

What sets them apart is that beyond these motor properties, mirror neurons are also activated simply by observing objects, irrespective of any intention, necessity, or potential to interact with them. This implies that the sensorimotor system automatically extracts the object's affordances and encodes them in terms of potential actions, even within the motor system.

Evidence suggests that a parallel process occurs not only when individuals observe others' actions but also when they observe emotional facial expressions. For instance, witnessing happy faces triggers increased activity in the zygomatic major muscle, while observing angry faces leads to heightened activity in the corrugator supercilii muscle—the same muscle areas involved in expressing happiness and anger, respectively(Dimberg, 1982; Dimberg et al., 2000; Dimberg & Thunberg, 1998; Lundqvist & Dimberg, 1995).

In light of this and related findings, contemporary researchers like Gallese (2003) suggested a theory of "embodied simulation" and have concluded "that the same neural structures that are involved in processing and controlling executed actions, felt sensations, and emotions are active also when the same actions, sensations, and emotions are to be detected in others" (Gallese, 2003, p. 519).

Notably, this contemporary formulation of “embodied simulation” closely mirrors the early perspective of Gestalt psychologists Köhler and Koffka regarding the comprehension of another person's mental states. Interestingly, the discovery of mirror neurons, when viewed through the framework of embodied simulation theory, seems to validate a hypothesis presented and defended by Gestalt theorists during the 1920s to 1940s. During that era, Köhler and Koffka posited that understanding someone else's mental state largely results from the application of the overarching principle of isomorphism (Koffka, 1924, 1935; Köhler, 1970).

Essentially, the Gestaltists identified two types of isomorphism: internal or intrapersonal isomorphism and external or interpersonal isomorphism. In both cases, the concept of isomorphism suggests that when an individual perceives an object, there are formal resemblances between the structural properties of the object and the brain processes of the perceiver.

The traditions discussed here, often considered as the cornerstone theories of EC, all inherently challenge representationalism and reject the conventional idea that mental entities somehow mirror the external world. The inclination toward anti-representationalism has sometimes been integrated into EC, while at other times it has not (Caruana & Borghi, 2013).

Chemero (2009) deems this distinction so crucial that he uses it to differentiate "Embodied Cognitive Science" (ECS) from "Radical Embodied Cognitive Science" (RECS).

ECS typically does not adopt an anti-representationalist stance; it usually employs simplified versions of mental representations, such as the concept of action-oriented, "non-neutral" representation, contingent on the subject's actions in the environment (Churchland, 2002; Grush, 2004; Millikan, 1995), or the reduction of the concept of mental representation to that of a predictive model of motor consequences (Gallese & Keysers, 2001).

Unlike ECS, RECS completely rejects the idea of mental representation because cognitive systems are dynamic and focused on action. The theory of dynamic systems provides a more fitting explanation for them. It intentionally avoids representation and sees cognition as a non-symbolic, emerging, context-dependent, historically-grounded, and embodied process (Thelen & Smith, 1998).

A dynamic system comprises a series of quantitative variables that perpetually fluctuate over time, interdependently, in accordance with a set of dynamic laws that can be articulated by specific equations. Hence, the theory of dynamic systems is exceptionally suited to elucidating the continuous interactions between the individual and the environment, as underscored by Gibson's ecological psychology (1979). The link between the individual and the environment is emancipated from the concept of representation and entrusted to alternative tools, such as "oscillators" – fortified by the fact that the elements of the central nervous system, neurons, and brain areas, all function as oscillators.

In conclusion, contrary to initial impressions, proponents of a "radical" form of EC are not fiery zealots or extremists who discard valuable aspects along with the superfluous, but rather they inherit the tradition of American naturalism, armed with robust tools and models (Chemero, 2009). On the contrary, ECS endeavors to amalgamate its radical iteration with the representational and computational theory of mind.

2. Embodied Cognitive Dimensions

The field of EC encompasses a wide range of subjects, making it impractical to comprehensively cover all aspects in a single treatise. This thesis provides an overview of selected cognitive dimensions explored by researchers in embodiment. It is important to note that within these various topics, two approaches can be distinguished: one emphasizing the role of the sensory domain, and another giving precedence to the motor domain in the process of embodying the mind. However, they share the underlying belief that the body, particularly the sensory-motor system, is an integral part of the mind's functioning.

2.1. Mental Processes Directed towards the External World: Objects and Other Individuals

2.1.1 Sensorimotor Processes and Embodied Cognition

A prominent area of debate between EC and classical representational theory centers around how we think and perceive objects. Sensorimotor processes, integral to our interactions with the environment, enable organisms to process sensory information and respond through coordinated motor actions. The perspective of the embodied mind suggests that these processes not only facilitate action but also significantly influence cognition (Barsalou, 2008). In line with this perspective, a compelling alternative called the "Perceptual Symbol System" theory was introduced in a series of influential works published from the late 1990s to the early 2000s (Barsalou, 1999).

This theory suggests that sensory information gathered during experiences isn't translated into abstract representations, but rather stored in higher-order sensory areas. Later, this allows for the reactivation of sensory features of an object through a process called "simulation," even when the object is absent. This means that cognitive processing not only reactivates sensorimotor areas during remembering but memory itself could potentially be constructed from sensorimotor patterns, making it modal rather than purely symbolic (Barsalou, 2003, 2009).

From this perspective, in addition to reflecting the nature of embodied interactions, the multimodal representations stored in memory aid, regulate, and facilitate processes such as perception, cognition, and contextual actions. This model effectively explains cognitive processes like memory, language, and reasoning, giving significant importance to the sensory aspect of cognition. To put it concretely, engaging our bodies in cognitive tasks, such as recalling information, addressing challenges, and creative thinking, often leads to more effective outcomes. This practice helps offload information, making the cognitive processes less demanding. For example, empirical studies have consistently shown that adopting specific body postures or facial expressions significantly enhances both the accessibility and retention of memories (Dijkstra et al., 2007; Glenberg, 1997; Niedenthal et al., 2005; Wilson, 2001, 2002). Furthermore, research has demonstrated that incorporating gestures during problem-solving enhances cognitive performance and promotes better comprehension and recall of information (Hostetter & Alibali, 2008).

These findings underscore that bodily movements and gestures are not merely incidental to cognitive processes, but actively contribute to cognitive activities, providing substantial support for the embodied cognition framework. This perspective underscores a reciprocal relationship between perception and action, highlighting how our bodily capacities, in tandem with the contextual backdrop, shape our overarching perception of the world.

However, one of the key observations in EC, widely recognized in psychology, neuroscience, and robotics, revolves around the activation of the motor system when observing objects and comprehending language related to them. In this context, researchers have revisited Gibson's concept of "affordance," albeit with a different interpretation than the original (for an overview, see Thill et al., 2013). Ellis & Tucker (2000) introduced the term "micro-affordance" in 2000, emphasizing both the similarities and differences with Gibson's notion.

As mentioned in Chapter 1, neuroscientific support for the concept of affordance is robust, primarily evidenced by the discovery of mirror neurons (Rizzolatti & Craighero, 2004; Rizzolatti &

Fadiga, 1998) within the motor system that activate simply upon observing graspable objects, regardless of the intention to interact with them. This has bolstered the neurophysiological interpretation of the concept of affordance. For instance, in a well-known study by Tucker and Ellis (2000), participants were shown objects of various sizes and tasked with responding by exerting either a forceful or a precise grip. The findings suggest that, even when participants were required to categorize objects as either artifacts or natural, they couldn't help but take their size into consideration. Consequently, they responded more swiftly with a forceful grip to larger objects (e.g., hammer, apple) and more slowly with a precise grip to smaller objects (e.g., fork, cherry).

This serves as an illustrative case, with numerous studies delving into this aspect. In contrast to the initial interpretation that considered affordances as static, automatic representations entrenched in the motor system and reactivated independently of the subject's task, a dynamic viewpoint gained traction. According to this perspective, studies have shown that the activation of affordances is influenced by a range of variables. These variables include the nature of the task (e.g., processing the object's shape versus irrelevant features like color, Pellicano et al., 2010; Tipper et al., 2006) to the spatial positioning of objects (within arm's reach versus further away Costantini et al., 2010, 2011), the object's functionality (functionally linked objects versus those associated solely by spatial proximity, Borghi et al., 2012; De Stefani et al., 2012; Yoon et al., 2010), numerical cognition (Fischer, 2012), social context (Becchio et al., 2012; Sartori et al., 2009), the individual's personal experiences, as evidenced in studies involving athletes (Pezzulo et al., 2010; Urgesi et al., 2012), and the handedness preference of participants (Apel et al., 2012).

The exploration of affordances also extends to language comprehension, a domain typically seen as abstract in classical representationalism theory. Numerous studies have demonstrated that reading or hearing words or phrases describing actions or manipulable objects activates areas of the motor system (Hauk et al., 2004; Tettamanti et al., 2005).

This suggests that the meaning of certain words or phrases is influenced by, or enriched through, the activation of the same sensorimotor systems engaged when we interact with the physical world. Consequently, this implies that words and their associations should also be connected by affordances (Glenberg & Gallese, 2012; Glenberg & Robertson, 2000).

Nevertheless, there have been relatively few studies examining the influence of cultures and the "conventionality" of affordances. Consider, for instance, the different affordances a fork might evoke for someone raised in Italy compared to someone raised in Japan (Menz et al., 2010). Furthermore, the exploration of affordances has expanded into the domains of computation and robotics. This expansion has been facilitated by the development of engineering or computational models, which seek to either emulate the neural basis (Bonaiuto & Arbib, 2010; Caligiore et al., 2010). However, it is within the realm of social interaction and intersubjectivity that EC has significantly advanced our understanding of the mind. Consider, for instance, the widely recognized discovery of "mirror neurons," (Gallese, 2006; Rizzolatti & Craighero, 2004) which has represented a true revolution in areas such as empathy, emotions, language, art, psychopathology, and rehabilitation.

In parallel with the identification of a mirror system situated within the fronto-parietal motor circuits, numerous mechanisms have been unveiled. These are affiliated with domains beyond the motor realm, leading the progenitor of this discovery, Giacomo Rizzolatti (Rizzolatti & Craighero, 2004), to advocate for moving beyond the concept of a "mirror system" and embracing the more encompassing term "mirror mechanism" It is the mirror mechanism, along with the broader experimental framework it encompasses, that has yielded some of the most intriguing insights into developmental disorders like autism (Gallese et al., 2013). The narrative of how this perspective has challenged cognitive-centric theories of autism, pivoting towards the somatic and motor domains, stands as an exemplary illustration of embodied cognition's potential in arenas that might initially appear predominantly theoretical (Gallese, 2006, 2009).

2.1.2 Social Interactions and Embodied Cognition

Social interactions are a fundamental dimension of human experience and are intricately linked with EC. The embodied mind perspective acknowledges that our capacity to perceive and interpret social cues is rooted in the body and its sensorimotor capacities (Varela et al., 1991; Wilson, 2002). This segment delves into the impact of social interactions on EC, encompassing elements of joint attention, empathy, and language.

Joint attention, denoting the mutual focus of attention between individuals, constitutes a pivotal facet of social interactions. Research indicates that joint attention necessitates synchronization between attentional, perceptual, and motor processes, underscoring the embodied essence of this social phenomenon (Skulmowski et al., 2016). Through participating in joint attention, individuals not only synchronize their attentional states but also establish shared cognitive and affective encounters.

Empathy, the aptitude to comprehend and resonate with the emotional states of others, stands as another critical facet of social interactions. The embodied mind perspective posits that empathy springs from the emulation of others' experiences within our own corporeal framework (Mahon & Caramazza, 2008). For example, witnessing someone in pain activates analogous neural circuits in the observer's brain, culminating in a vicarious experience of the other person's distress (Wilson, 2002). This congruent neural activation exemplifies the embodied quality of empathy, wherein the body assumes a central role in comprehending and resonating with others' emotions.

Language, a fundamental medium for communication and social engagement, is similarly closely entwined with EC. Studies have demonstrated that both language comprehension and production entail sensorimotor simulations, wherein linguistic representations are firmly rooted in our corporeal encounters and activities (2010). For instance, terms associated with bodily actions trigger corresponding motor regions in the brain, attesting to the embodiment of language processing.

2.2 Mental Processes Directed towards the Internal World

2.2.1 The "embodied self" as a novel concept

As argued by Borghi & Caruana (2013) the distinction between cognitive processes oriented externally and those turned inward may be somewhat arbitrary, with boundaries that are not entirely rigid. Its purpose, more as a rhetorical device than a precise classification, is to emphasize how an entire category of studies gained prominence in psychologists' discourse following the advent of EC.

Apart from the discussed themes, EC has ventured into various cognitive processes focused on the inner domain and the body. These areas of inquiry were not easily accommodated within the framework of cognitivism, and if attempted, often resulted in less impactful theories. An illustrative instance is the expansive realm of embodied theories concerning emotions.

Furthermore, EC has reappropriated certain conceptual distinctions drawn from phenomenology and classical neuropsychology. This has enabled a (neuro)scientific exploration of bodily experiences. Among these distinctions, the classic differentiation between "body schema" and "body image" is noteworthy, alongside the more recent demarcation between "sense of agency" and "sense of ownership". These theoretical constructs have given rise to the formulation of a novel concept - the "embodied self", a notion that straddles the domains of neuroscience and phenomenology. It has proven to be an insightful interpretative framework, particularly in comprehending psychiatric disorders like schizophrenia (Ferri et al., 2012). The systematic inquiry into bodily phenomenology has unveiled fresh psychological perspectives, addressing implicit gaps in classical amodal representational theories.

2.2.2 Emotions: embodiment and affective processing

Emotions constitute an integral facet of human experience, and the embodied mind perspective underscores the profound interconnection between emotions and bodily encounters (Damasio, 1991).

Evidence substantiate the close association between bodily sensations and expressions with emotional experiences. Notably, studies have demonstrated that replicating facial expressions linked to specific emotions can induce corresponding emotional states in individuals, providing empirical support for the concept of embodied emotional experiences (Niedenthal et al., 2005). These revelations affirm that our bodily expressions and sensations are not mere outward displays of emotions, but active contributors to the very experience and perception of emotions.

Moreover, emotional embodiment assumes a pivotal role in the regulation of emotions. This process involves a range of cognitive and physiological mechanisms aimed at modulating emotional experiences. As an example, interventions rooted in bodily engagement, such as participating in physical activities or adopting specific postures, can exert discernible effects on emotional states and regulation strategies (Decety & Grèzes, 2006). This underscores the direct impact that bodily engagement can have on emotional well-being and regulation.

Additionally, emotional embodiment exerts influence over memory processes. For example, charged events tend to be retained more vividly than neutral ones, and the bodily sensations accompanying these emotional episodes contribute significantly to the encoding and retrieval of emotional memories (Gazzola & Keysers, 2009). In other words, the bodily responses associated with emotions serve as distinctive markers that enhance the encoding and retrieval of emotional experiences, underscoring the intricate interplay between emotional embodiment and memory.

This perspective collimates to contemporary neuroscientific revelations concerning the essence of perception. For instance, a deficit in emotional perception may be induced by peripheral-level obstruction of emotional expression. A copious body of literature attests that the injection of botulinum toxin into facial musculature implicated in emotional expression attenuates the corresponding emotional experience (Davis et al., 2010). To put it concretely, when simulating an angry emotional expression, a subject who received a botulinum toxin injection showed reduced activity in the left amygdala, a key center responsible for coordinating vegetative responses at a higher level. This decrease in activity was also observed in the brainstem, an ancient brain structure directly influencing vegetative responses. The diminished activity in these structures suggests a simultaneous reduction in sensory feedback input and a suppression of visceral motor responses, all under the control of the mentioned structures (Hennenlotter et al., 2009).

Similarly, deliberately adopting a specific facial expression or emotional posture can predispose an individual toward experiencing the corresponding emotion. This, in turn, influences how emotional information is processed (Niedenthal, 2007).

In this vein, in a now-classic study (Davis et al., 2010), groups of volunteers were asked to hold a pen either between their teeth (resulting in an involuntary smile) or between their lips (resulting in an involuntarily furrowed expression). Simultaneously, they were tasked with rating the amusement level of certain cartoons shown during the experiment. This experiment, for the first time, demonstrated that facial expressions associated with a smile, even if involuntary, led participants to rate the stimuli as more amusing. This judgment contrasted with the group that had involuntarily furrowed brows.

2.3 Embodied, Situated, Grounded, Enacted (Cognition)

In the last two decades, a wealth of data, particularly within the realms of psychology and neuroscience, has been accumulated. This has led to a situation where the term "embodied cognition" has expanded to encompass a spectrum of concepts. It generally denotes the idea that cognition is intricately linked with bodily and environmental factors. However, cognitive processes have, in turn, been assigned various labels, including "embodied," "situated," "grounded," or "enacted." Despite their frequently interchangeable use, these labels harbor subtly distinct theoretical perspectives. In this vein, in order to achieve a conceptual clarification, a notable hierarchical structuring of *grounded, embodied,* and *situated* cognition can be identified (Fischer, 2012).

Particularly, Fischer (2012) presented a hierarchical conceptual framework for understanding their interrelationship, employing the suffix "-*ness*" to emphasize the need for precise diagnostic attributes that determine the dominant level of knowledge representation influencing performance.

According to Fischer, we should interpret *Groundedness* as a reflection of universal principles in cognition that appear as constants in the physical world. For example, the evident observation that it takes more time to rotate an object through a larger angle serves as the foundation for the gradient in decision times when participants categorize tilted objects as either normal or mirror-imaged (Shepard & Metzler, 1971). This phenomenon, known as the mental rotation effect, suggests that there is a systematic relationship between the angle of rotation and the time it takes for our cognitive processes to handle such mental tasks. Additionally, the concept of *Groundedness* is apparent in the realm of numerical cognition, as there is a consistent connection between small magnitudes and lower space, as well as larger magnitudes and upper space. This association of numerical concepts with spatial orientation has been observed through saccadic latencies in Dutch participants (Schwarz & Keus, 2004) and button presses in both Japanese (Ito & Hatta, 2004) and Israeli participants (Shaki & Fischer, 2012).

The term *Embodiedness* should encompass performance characteristics that mirror the sensory and/or motor constraints of the human body. The body, being a physical entity, is subject to the physical limitations of the world; however, it also possesses various unique ways of interacting with its surroundings. Therefore, *Embodiedness* encapsulates the narrative of sensory and motor encounters that shape the learning background of an individual. For recent reviews of individual variations in *Embodiedness*, refer to Casasanto (2011) and Keehner and Fischer (2012).

Another illustration of *Embodiedness* is the consistent relationship between number magnitude and grip aperture. In a study conducted by Andres et al. (2004), healthy adults, when tasked with indicating the parity of visually presented digits through either grip opening or grip closure, exhibited faster closure of their grip in response to small numbers and opening of their grip in response to large numbers. This outcome is presumed to mirror the lifelong pattern of interacting with small objects using precision grips and larger objects using power grips. Another example of *Embodiedness* is the presumed origin of Spatial-Numerical Association of Response Codes (SNARC, Dehaene et al., 1993) in finger counting. Although the directional bias of SNARC was initially attributed to reading direction (Berch et al., 1999; Zebian, 2005), more recent studies confirm the presence of SNARC in preschoolers and point to observational learning and imitation of directional counting habits in adults as sources for the bias (review in Fischer & Brugger, 2011). Notably, in alignment with these findings, the study by Tschentscher et al. (2012), demonstrated spontaneous finger cortical activation in response to passive number viewing.

Finally, the *Situatedness* of cognition reflects the current constraints on the accessibility of knowledge imposed by the state of the body and its environment. This level of knowledge representation is highly adaptable and promptly adjusts to ever-changing task demands. For instance, individuals adopting a reclining posture are more likely to recall details of a visit to the dentist than those in upright postures (Dijkstra et al., 2007), indicating that postural constraints reactivate memories of events experienced in a similar posture. A comparable demonstration of *situated* numerical cognition involves the impact of postural orientation on the retrieval of number knowledge. Lo¨tscher et al. (2008) revealed that healthy adults tend to generate smaller random numbers, on average, when their head is turned to the left side and larger random numbers when their head is turned to the right side.

On the contrary, in contrast to *grounded, embodied* and *situated* cognition, which centers around the investigation of cognitive processes, *enactivism* positions perception at the core of its exploration (Read & Szokolszky, 2020).

Expanding beyond these categorizations, as proposed by Borghi & Caruana (2013), EC is influenced by two distinct magnetic forces: one oriented towards perception and the other towards action. It is noteworthy to observe how the utilization of various labels such as grounded, embodied, situated, often aligns with emphasizing one pole over the other. Beyond mere semantic distinctions, it has been established that the concept of "grounded" is more prominently linked with the idea of basing cognitive processes on sensory inputs. "Embodied" relates to the inclusion of motoric elements, while "situated" is prominently associated with the dependence of cognition on the environment.

3. The Body Specificity Hypothesis

3.1 Theoretical Background

3.1.1 The interplay between diverse bodies and minds

In line with theories of EC, it is posited that thoughts consist of mental simulations of bodily experiences (Barsalou, 1999; Feldman, 2006; Goldstone & Barsalou, 1998; Lakoff & Johnson, 1999; Prinz, 2004). Within this framework, it is argued that individuals with different physical attributes (bodies) engage in distinct modes of thought ("think differently"). Essentially, if concepts and word meanings are, in part, constructed through simulations of one's own perceptions and actions, individuals with diverse bodily characteristics, who interact with their physical environments in systematically different ways, should consequently form correspondingly different mental representations. This perspective is supported by the hypothesis presented by Casasanto (2009).

In Casasanto's studies, five experiments were conducted to examine a hypothesis and address two specific challenges in advancing theories related to embodied mental representation. The first challenge involved designing experiments that would yield contrasting predictions between embodied theories and their alternatives. The second challenge centered around determining the experiential origins of mental representations, even in abstract conceptual domains.

Specifically, Casasanto hypothesized that distinct attributes of our bodies might shape our mental representations of concrete objects and actions. For instance, if contemplating objects involves mentally simulating their colors, then the mental representations of apples should exhibit qualitative differences between individuals with red-green color blindness and those with normal vision (Simmons et al., 2007). Similarly, thinking about actions would likely involve mentally simulating how we typically execute them. This implies that actions performed with our dominant hands, such as throwing a ball, turning a key, or signing a check, may yield different neurocognitive representations in right-handed and left-handed individuals (Longcamp et al., 2005; Willems et al., 2010). However, the applicability of body-specificity to the mental representation of abstract concepts like morality, success and failure, deceit and honesty, presents a distinctive challenge for embodied theories. Casasanto raises this issue by questioning the ways in which perceptuomotor simulations can contribute to representing things that surpass sensory perception or muscular action. According to Casasanto, abstract concepts, including those mentioned, are frequently linked with either positive or negative emotional valence.

As an illustration, in various languages, including English, metaphorical expressions tend to link positive and negative valence with the top and bottom of a vertical spatial continuum (Lakoff & Johnson, 1980, 1999). For example, a happy person is often described as being "high on life," while a sad person might be said to be "down in the dumps." These linguistic metaphors, according to metaphorical mental representation theories (e.g., Lakoff & Johnson, 1999), reflect underlying mental metaphors (Casasanto, 2008). These nonlinguistic associative mappings extend from the concrete source domain of space to relatively abstract target domains characterized by positive or negative valence. Empirical studies offer support for the idea that mental metaphors derived from physical space influence our conceptualizations not only of concepts with emotional valence (Casasanto & Dijkstra, 2010; Meier & Robinson, 2004) but also of time (Boroditsky, 2000, 2001; Casasanto & Boroditsky, 2008), numerical quantity (Dehaene et al., 1993), emotional attachment (Williams & Bargh, 2008), power (Schubert, 2005), and similarity (Casasanto, 2008) even in the absence of explicit linguistic metaphors (Murphy, 1996, 1997).

As argued by Casasanto (2009), mental metaphors offer a potential resolution, at least in part, to the challenge of representing abstract ideas through embodied simulations. Deliberations about affective states or the formation of affective judgments may engage mental simulations in both source and target domains. Representations in the target domain could involve partial recreations of emotional states in the brain regions responsible for the generation of emotional experiences. For example, simulating affection could entail reenacting patterns of activity in the nucleus accumbens responsible for the interoceptive experience of affection, while simulating fear could involve reenacting patterns of activity in the amygdala responsible for the experience of fear (Damasio, 2001). These rudimentary representations in the target domain may be too indistinct or fleeting to support higher-order reasoning about emotional states, and they may be less amenable to verbal and imagistic coding that can facilitate such reasoning.

Mental metaphors introduce the inferential structure of source domains, such as spatial concepts, into target domains, enabling us to envision, quantify, and compare dimensions of people's emotional states, like the intensity of their excitement, the depth of their sadness, or the breadth of their compassion (Boroditsky, 2000; Pinker, 1999). Insofar as mental representations in perceptuomotor source domains constitute abstract concepts, these concepts can be instantiated by the same neural and mental structures that simulate perception and action in the physical world.

3.1.2 Mental Metaphors: Valence and Vertical Space

Extensive evidence supporting the existence of mental metaphors has accumulated, yet their experiential roots remain elusive. Two distinct theories have emerged from separate bodies of literature. The first suggests that mental metaphors arise from connections in physical experiences, while the second attributes them to correlations in linguistic experiences. According to the first theory (e.g., Lakoff & Johnson, 1999), mental metaphors like "Positive Is Up" and "Negative Is Down" could develop as individuals implicitly form associations between physical experiences and corresponding emotional states that often occur together (e.g., standing tall when feeling proud, slouching when feeling dejected). These linguistic metaphors then encode preexisting mental metaphors, which are established based on the relationships between different types of bodily experiences (i.e., perceptuomotor experiences in source domains and interoceptive experiences in target domains). Social psychological studies have been interpreted as providing support for this proposal (Barsalou et al., 2003). As an example, in one study, participants exhibited greater persistence in a puzzle-solving task when adopting an upright posture compared to a slouched one

(Riskind & Gotay, 1982). Another study showed that participants expressed more pride in their test performance when sitting upright during a crucial phase of the experiment, as opposed to slouching (Stepper & Strack, 1993).

In contrast, according to the alternative proposal, mental metaphors form by linguistic metaphors. For example, using spatial words, both literally and metaphorically (e.g., a *high* shelf, a *high* ideal), could lead elements from the concrete source domain to be transferred to abstract representations in the target domain within the mind of a language learner, through analogical processes that aren't necessarily "embodied" (see Boroditsky, 2000; Gentner et al., 2001).

As argued by Casasanto (2009) one reason to consider this possibility is that associations between valence and vertical space have been observed to extend beyond concepts that have clear perceptuomotor correlations. As an example, in the Meier & Robinson (2004) study, participants were quicker to assess words like "polite" and "rude" as having positive or negative valence (e.g., decisional lexical task) when positive words were presented at the top and negative words at the bottom of a computer screen.

In addition, following Casasanto (2009), linguistic conventions that link valence with vertical space are reinforced by other nonlinguistic cultural practices, such as the "thumbs up" and "thumbs down" gestures indicating approval and disapproval. Once these linguistic and nonlinguistic conventions are ingrained in a culture, they can serve as the foundation for metaphorical mappings in the minds of individual learners, bypassing the need for direct bodily experiences. Consequently, data supporting metaphor theory do not necessarily lend support to embodiment theory. Mental metaphors could be derived from patterns in language and culture. As Casasanto argued, behavioral effects revealing the existence of mental metaphors could arise from the spread of activation between nodes in a non-specific conceptual network that are habitually co-activated during language use, rather than stemming from correlated physical and emotional experiences.

3.1.3. Mental Metaphors: Valence and Body Sides

Beyond the correlation with vertical orientation, strong evidence indicates associations between valence and the right and left sides of the body. For right-handed individuals, engaging the right side (e.g., contracting right-hand muscles or the right side of the face) is linked to positive feelings, while similar actions on the left side are associated with negative emotions (Davidson, 1992; Natale et al.,1983). This link between valence and the body's sides may be related to motivational systems governing approach and avoidance behaviors. Approach tendencies are associated with the left frontal lobe (which controls the right side of the body), while avoidance tendencies are linked to the right frontal lobe (which controls the left side of the body, e.g., Davidson et al., 1990; Schiff & Bassel, 1996).

The same associations between right as "positive," and left as "negative," are reflected also in everyday language expressions. As suggested Casasanto (2009) English idioms and expressions like "the right answer" and "my right-hand man" link positive attributes with rightward direction, while idioms like "out in left field" and "two left feet" associate negativity with leftward orientation. Similarly, in many languages, words for "right" often imply "correct" or "privileged," in contrast, words for "left" are linked to notions of "awkward" or "undesirable."

Such idiomatic expressions extend into nonverbal customs in certain cultures, as seen in Ghanaian society in which using the left hand for pointing and gesturing is discouraged (Kita & Essegbey, 2001). Moreover, according to Islamic doctrine, the left hand is designated for tasks considered impure, while the right hand is reserved for eating. Additionally, when entering spaces such as bathrooms and mosques, the left foot and right foot are respectively used. Furthermore, in the Catholic religion, the left hand has been deemed the "devil's hand," to the extent of correcting left-handed children, teaching them to use their right hand instead of their left.

Furthermore, this preference for "valence based on direction" as hypothesized by Casasanto (2009) appears to be consistent across cultures, irrespective of the reading and writing direction.

Notably, in cultures with left-to-right writing systems such as English-speaking ones, the mental representation of numbers progresses from left to right. Conversely, in cultures using right-to-left writing systems like Arabic-speaking ones, the opposite is true (Chatterjee, 2001; Dehaene et al., 1993; Maass & Russo, 2003; Tversky et al., 1991; Zebian, 2005).

Thus, despite cross-cultural variations in horizontal mappings for concepts like number, linguistic and cultural conventions in both Arabic-speaking and English-based cultures align with the idea that "Good Is Right," as argued by Casasanto (2009). This suggests that valence is not significantly influenced by writing direction.

One plausible explanation for this apparently universal preference is that it stems from inherent characteristics of the human brain and mind, possibly related to the natural specialization of brain hemispheres for approach and avoidance motivational systems. Once established due to innate neurobiological factors, conventions in language and culture may further reinforce this implicit inclination towards the right (Casasanto, 2009).

However, Casasanto (2009) proposed an alternative possibility: that left-right conventions in language and culture arise as a result of body-specific associations between spatial orientation and emotional valence. Human bodies typically have a dominant hand, often the right hand (Corballis & Beale, 1976), leading to more fluent interactions on one side of body-centered space compared to the other. Research has shown that greater ease of motor movement (e.g., greater perceptuomotor fluency) correlates with more positive evaluations (Oppenheimer, 2008; Reber et al., 1998).

Thus, according to Casasanto's BSH (2009), across a lifetime of asymmetric motor experiences, individuals unconsciously associate positive qualities with the side of space they can interact with more skillfully, and negative qualities with the side of space they interact with less adeptly. Casasanto proposed that the perceived universality of the "Good Is Right" mapping, as indicated by linguistic and cultural conventions, might result from the global prevalence of right-handed individuals. In this vein, he emphasized that linguistic and cultural conventions could evolve in alignment with the implicit body-specific mental metaphors of the majority, primarily consisting of right-handed individuals. Consequently, the association where “Right is Good” could reflect the predominance of right-handed individuals in the global population compared to left-handed individuals.

In this scenario, Casasanto (2009) conducted five experiments to examine the associations between valence and horizontal space in both right- and left-handed individuals. The objective was to establish whether these mappings are consistent across all individuals (universal) or specific to certain bodily orientations (e.g., body-specific).

3.2 Experimental Studies by Casasanto (2009)

Casasanto’s Experiment 1 (Casasanto, 2009) involved a pencil-and-paper task where participants had to draw animals in boxes around a cartoon figure. In one set-up, the boxes were placed to the left and right of the figure (horizontal condition), and in another set-up, they were arranged above and below the figure (vertical condition). Participants were instructed to place animals they thought were good in the box representing positive things, and animals they thought were bad in the box representing negative things. Casasanto called this task the “Bob goes to the zoo task”. The horizontal condition aimed to test whether the spatialization of valence is specific to the body. Casasanto hypothesized that if it is body-specific, right- and left-handed individuals would have opposite preferences for placing good and bad animals in the left and right boxes. Conversely, he proposed that if the spatialization of valence is universal, both groups should exhibit a preference for placing good things on the right, aligning with linguistic and cultural conventions. The vertical condition served as a control.

In the vertical condition, as expected, since participants all shared the same cultural and linguistic associations linking “up” with positive, regardless of handedness, placed the good animal on top and the bad animal on the bottom. Specifically, both left-handers (89%) and right-handers (83%) predominantly placed the good animal in the top box and the bad animal in the bottom box.

Considering these results, Casasanto concluded that there was no significant association between handedness and top-bottom placement.

Instead, in the horizontal condition, a significant majority of left-handers (74%) placed the good animal on the left side, while most right-handers (67%) placed it on the right. Statistical tests confirmed this pattern, indicating a strong correlation between handedness and left-right placement. In particular, the odds ratio (OR) from logistic regression suggested that right-handers were nearly six times more likely than left-handers to make this placement. In summary, the Experiment 1 found a body-specific association between handedness and horizontal space (e.g., space valence associations) in the placement of good and bad animals. Right-handers predominantly associated good with the right space, while left-handers associated it with the left space.

Afterwards, Casasanto sought to determine whether participants in Experiment 1 (Exp.1) were consciously aware of how their handedness influenced their judgments (Experiment 2; Exp.2). Exp. 2 (Casasanto, 2009) replicated the task of Exp. 1 with some changes: it included a debriefing, replaced certain questions (e.g., asking participants to speculate on the purpose of the task and explain their answers), and added an objective measure of handedness. Additionally, it involved native Dutch speakers to extend the findings of Exp. 1 to a different population, as the Dutch language and culture, like English, also associate “good” with “right.” This facilitated assessing the universality of the observed effects. Notably, Exp. 2 replicated the findings of Exp. 1 in a new participant population and showed that the observed space-valence associations were not dependent on participants being consciously aware of their handedness. Experiment 3 (Exp.3) aimed to investigate whether body-specific associations were present when participants were asked to respond without using their hands, to avoid any effects related to task-related preferences for the side of space easiest to interact with in the moment (e.g., writing and drawing with one’s dominant hand). Exp. 3 mirrored the findings of Exp.1 and Exp.2, suggesting that the results were not dependent on the mode of response and could not be attributed to performance factors such as temporary convenience in interacting on one side rather than another.

Building upon the precedent set by Experiments 1-3, Experiment 4 (Exp.4) aimed to investigate whether the left-right positioning of stimuli (alien creatures) subtly influenced the evaluations of positive or negative traits for both right- and left-handers. The findings replicated the results of previous experiments: left-handers demonstrated a stronger inclination towards a 'Good Is Left' bias, while right-handers leaned towards a “Good Is Right” bias. Specifically, most left-handers (65%) associated positive characteristics more frequently with the alien creature (“Fribbles”) on the left side, while a slight majority of right-handers (54%) favored “Fribbles” on the right side. These findings are particularly significant, given the use of alien creatures as stimuli, especially considering that in Exp.1, potential subjective experiences with animals might have influenced the outcomes in the “Bob goes to the zoo task.” To address this concern, Casasanto extended the investigation to alien creatures, mitigating potential biases through the inherent strangeness of the stimuli.

In the last experiment (Experiment 5, Exp.5), the aim was to extend the investigation of body-specific spatial influences to everyday decision-making scenarios on Earth. Instead of evaluating novel images without pre-existing semantic associations, participants were tasked with assessing concise verbal descriptions of job applicants (in the job task) and common products one might encounter in advertisements, such as those found in newspapers or websites (in a shopping task). Among participants with a directional preference, the majority of left-handers (74%) tended to attribute positive characteristics more frequently to people or products on the left side of the page. Conversely, a slight majority of right-handers (52%) favored items on the right side. This handedness-specific pattern was statistically significant and consistent with the previous experiments (1, 2, 3, 4). Additionally, the study reported that right-handers were more than three times as likely as left-handers to associate positive responses with the right side of the page. These findings provide strong evidence in support of the BSH across all conducted experiments.

Importantly, all the experiments we have considered investigate the space-valence association as an extracorporeal phenomenon, focusing on the spatial location of stimuli related to participants' preferences for one side over another across horizontal space. Interestingly, if body specific associations were linked to participants' hands, the same phenomenon could be considered an intracorporeal one (i.e., hand compatibility effect).

Specifically, studies employing response time paradigms, where participants react to positive words with the dominant hand and negative words with the non-dominant hand, have revealed hand compatibility effects (de la Vega et al., 2012; Kong, 2013). Particularly, participants were consistently faster in reacting to positive words with the dominant hand and faster to negative words with the non-dominant hand, even when hands and side conveyed incongruent information (de la Vega et al., 2013). As mentioned before, these results delve into the intracorporeal origin of body specific associations, suggesting that these associations are more closely tied to the hand than the space.

Intriguingly, the intracorporeal effect is just one among a plethora of diverse multimodal manifestations associated with the BSH. Casasanto (2009) employed only binary choice tasks (Exp. 4, 5) and tasks related to the spatial positioning of items (animals and alien creatures, Exp. 1, 2, 3) Undoubtedly, this choice was made to ensure consistency across all five experiments but also to pave the way for further investigations involving different tasks and paradigms, such as the response time paradigm. The upcoming paragraph will delineate these varied multimodal manifestations and shed light on the latest advancements following the discovery of the BSH. This endeavor aims to provide a comprehensive overview of recent investigations, each distinguished by different methodological approaches.

3.3 Unraveling the Body Specificity Hypothesis: An In-depth Analysis of Evidence and Comparison

3.3.1 The multidomain facets of body specific associations

The initial findings by Casasanto (2009) sparked a new line of research exploring space-valence associations across diverse domains (e.g., auditory, real-life communicative processes) and cognitive levels like recognition and memory. For instance, in a study conducted by Giuliani et al. (2018), space-valence associations were observed in a visual recognition task. Specifically, participants recognized a 100-euro banknote (associated with a more positive connotation) faster in the right visual field (pressing the key 'p' with the right index), while there was no difference in the left visual field (pressing the key 'u' with the left index). The authors interpreted this effect as resulting from the match between the positive valence conveyed by the 100€ banknote and the side to which it was mapped (right-positive).

Intriguingly, real-life communicative processes in multimodal settings revealed similar associations. In a study by Casasanto and Jasmin (2010) analyzing presidential debates, positive speech was observed to be linked to right-hand gestures in right-handed candidates (Bush and Kerry), while negative speech correlated with left-hand gestures. This pattern reversed in left-handed candidates (McCain and Obama). Notably, prior to the conceptualization of the BSH (Casasanto, 2009), body-specific associations were observed in the auditory domain. Right-handers tended to experience more positive emotions when music was presented to their right ear (McFarland & Kennison, 1989).

In this vein, evidence suggests that humans exhibit a preference for being addressed in their right ear, and they are more likely to comply with requests when received in the right ear compared to the left (Marzoli & Tommasi, 2009). These findings, based on three studies investigating ear preference in communication, illuminate a natural side bias influenced by hemispheric brain asymmetry. The authors focused on observing ear preference during social interactions in noisy nightclub environments rather than controlled laboratory settings. In the first study, 286 clubbers were observed talking in the presence of loud music, revealing that 72% of interactions occurred on the right side, aligning with the right ear preference found in laboratory studies and questionnaires. The second study involved approaching 160 clubbers, mumbling an inaudible utterance, and waiting for them to offer either their left or right ear. When subsequently asking for a cigarette, 58% offered their right ear for listening, and 42% offered their left, with only women consistently showing a right-ear preference. The researchers found no link between the number of cigarettes obtained and the ear receiving the request. In the third study, the researchers intentionally addressed 176 clubbers in either their right or left ear when requesting a cigarette. The results showed a significant increase in the number of cigarettes obtained when speaking to the clubbers' right ear compared to their left. The authors concluded that these results support the idea of a right ear/left hemisphere advantage for verbal communication, indicating distinctive specialization of the brain hemispheres for approach and avoidance behavior.

Furthermore, a study conducted by Brunyè et al. (2012) revealed that handedness influences the coding of affective information, with both right-handed and left-handed participants consistently demonstrating biases in spatial location memory based on associated emotional information. Regardless of handedness, individuals displayed ongoing biases in recalling positively valence-laden locations as further to the right and negatively valence-laden locations as further to the left, compared to their actual positions. Stronger right- or left-handedness, as measured by the Edinburgh Inventory (Oldfield, 1971) resulted in more pronounced spatial memory biases.

Moreover, evidence highlights the bidirectional relationship between space and valence. For instance, positive biographic memories led to more rightward movements, while negative memories led to more leftward movements (Fernández et al., 2019). In this study, 67 right-handed participants freely stepped on an 8-response pad after being presented with positive and negative life-events. The significant finding indicated that approach-avoidance behaviors and space-valence associations across laterality were intricately connected during whole-body step actions: positive events induced steps biased toward front-right, while negative events induced steps biased toward back-left.

Similarly, individuals tended to gaze longer to the right when exposed to positive information and to the left when listening to negative information. Specifically, in a study by Çatak et al. (2018), 40 left-handed participants viewed faceless gesture videos containing negative and positive content while their eye movements were tracked. The study found no significant handedness-related differences in comprehension. However, an emotional valence effect on gaze direction was observed, with participants tending to gaze longer to the right (actor's left) when exposed to positive information and to the left (actor's right) when listening to negative information.

Consistently with these findings, in an experiment evaluating skiers' performances in dual mogul competitions, participants consistently favored skiers on their dominant side (Loffing et al., 2019). Loffing and colleagues (2019) investigated the impact of body-specific influences on evaluative judgments within realistic dynamic scenes. In two experiments with right-handed participants (N=231), videos of dual mogul competitions were shown, and participants provided comparative ratings of skiers' technical performances. Experiment 1 involved forced-choice decisions between left and right skiers, revealing significant body-specific associations. However, in Experiment 2, where graded judgments on a 10-point scale were made, body-specific associations were not observed. A control experiment (Experiment 3) confirmed the presence of body-specific associations, particularly in tasks demanding forced-choice decisions. The authors suggest that body-specific associations extend to realistic dynamic scenes, especially in tasks requiring forced-choice decisions.

Importantly, Casasanto's (2009) findings were also replicated in right-handed individuals with footedness (Weber & Sun, 2020) in two simple motor tasks, utilizing their hand (Task 1) and foot (Task 2) to move a monster cutout to one of two boxes placed on the left and right of a cartoon figure. Likely to the “Bob goes to the zoo task,” the instructions emphasized that the cartoon figure perceived certain monsters as good and others as bad. Participants were required to move the monster deemed “good” to the box representing positive things and the “bad” monster to the box associated with negative things. Valence assignments and task order were counterbalanced across participants. Consistent with previous findings, results indicated that a majority (74%) of right-handers assigned the good monster to the right box in the hand task. Similarly, a majority (72%) of individuals with a preference for their right foot assigned the good monster to the right box in the foot task. However, the association between valence and left-right foot space was less pronounced in participants with no foot preference (N = 17). Among these individuals, 58% moved the good monster to the right box using their foot.

3.3.2. The flexibility of space valence associations

As argued by Casasanto (2009) since space-valence associations are grounded in the motor fluency experienced during interactions with the environment, it might be worth questioning the flexibility of these associations. Following this consideration, he hypothesized that any variations or changes in motor fluency should alter the conceptualization of valence.

To test this hypothesis, Casasanto and Chrysikou (2011) manipulated the fluency of participants' hands in a motor task (i.e., dominos) and investigated its influence on spontaneous space-valence associations. Specifically, both right- and left-handed participants manipulated dominos with both hands while wearing a bulky ski glove on either their dominant or non-dominant hand to reduce the fluency of the hand wearing the glove. A few minutes after the motor task, participants removed the glove and were tested with the oral version of the association task (i.e., the Bob goes to the zoo task, as described by Casasanto in 2009, here reported in Chapter 3).

Results from participants who wore the glove on their non-dominant hands replicated Casasanto’s (2009) findings. However, unexpectedly, participants who wore the glove on their dominant hand exhibited a reversed pattern. In other words, right-handers tended to place good items on the left side and bad items on the right side (reflecting the typical pattern of left-handers), while left-handers presented the typical pattern of right-handers. These results were interpreted in favor of the BSH suggesting that variations in how participants used their bodies to act led to variations in how they conceptualized the abstract notion of valence.

Illustrating this phenomenon, a study involving individuals afflicted by stroke (Casasanto & Chrysikou, 2011) provided compelling evidence substantiating the pivotal significance of motor experiences in the context of the BSH. Interestingly, these subjects were tasked with completing the "Bob goes to the zoo task" (Casasanto, 2009), allowing for the scrutiny of enduring shifts in motor fluency. Intriguingly, it was observed that all patients who retained their right-handedness post-stroke consistently favored the right receptacle for categorizing the "good animal." Conversely, those who transitioned to left-handedness post-stroke demonstrated a predilection for the left receptacle for the same categorization. This preference diverged from their pre-morbid right-handed orientation. As argued by the authors, these empirical observations suggest that the connection between affective valence and spatial orientation transcends the natural disposition of handedness and may instead be a manifestation of heightened fluency in executing actions on one's dominant side. In other words, these findings highlight that space-valence associations are not fixed but may vary as a result of acting more fluently with one side rather than the other. These findings have been corroborated by previous studies (Beilock & Holt, 2007; Cannon et al., 2010) suggesting that fluency (i.e., the ease of performing an action) associated with certain actions and objects can influence people's preferences.

Specifically, in the Beilock & Holt study (2007) skilled and novice typists were asked to indicate their preference between two letter dyads. In each pair, one dyad, if typed using standard methods, involved the same fingers (e.g., FV), while the other would be typed with different fingers (e.g., FJ). Therefore, dyads of the former kind (i.e., same fingers) were expected to induce more motor interference than dyads of the latter kind (i.e., different fingers). Despite participants' inability to articulate the differences between the dyads, skilled typists exhibited a preference for those typed with different fingers, whereas novices showed no preference. Additionally, engaging in a motor task while making dyad preference judgments reduced the preference of skilled typists, specifically when the motor task involved the fingers used to type the dyads (left index, right index, and right-middle fingers). As argued by the authors, these findings suggested that, in skilled typists, perceiving letters triggers a covert sensorimotor simulation of typing, subsequently influencing affective judgments regarding this information.

In this vein, Cannon et al. (2010) investigated the impact of sensorimotor fluency on affective reactions during a categorization task involving objects. In trials with fluent stimulus-response (s-r), grasp-compatible objects were presented on the same side of the screen as the response hand, while in non-fluent trials, grasp-incompatible objects were presented on the opposite side of the screen. Affective responses were measured using electromyography to assess face muscle activity. Participants exhibited greater activity in cheek muscles (associated with smiling) during trials with s-r compatible responses compared to those with incompatible responses. As the authors suggested, these findings align with hedonic models of fluency, suggesting that fluent processing induces a direct emotional experience.

Moreover, in a review study by Ping et al. (2009), it was concluded that, when we act, we like to do what is easy for us, and we also preferer objects that are easier to act on. Indeed, in a study by the same author (Ping et al., 2009) participants (all right-handed participants, 45 in total) were asked, in a task, to indicate which object they preferred the most. They choose non-affective objects (i.e., kitchen utensils) that they could easily grip, without obstacles.

3.3.3 The relationship between fluency and valence in response time paradigms

Support for the BSH has been documented in various studies (de la Vega et al., 2012, 2015; Kong, 2013; Milhau et al., 2013, 2015), using a response time paradigm to investigate the influence of action (i.e. fluency) on affect (i.e. valence).

Specifically, a study conducted by de la Vega et al. (2012) showed that processing valence-laden words (items or entities carrying a strong emotional charge or conveying a particular positive or negative value) facilitated compatible motor responses of the dominant or non-dominant hand (i.e., the affective hand connotations effect).

To illustrate this phenomenon, in a lexical decision response time procedure, right-handed participants, when explicitly focused on the valence and side mapping of valence-laden words, exhibited faster judgments for positive words with their dominant hand, pressing a key on the right side of the keyboard. Conversely, negative words were evaluated more quickly when participants used their non-dominant hand to press a key on the left side of the keyboard. This effect was also observed in left-handed participants, who displayed the opposite pattern of behavior compared to that of right-handers.

In addition, the hand compatibility effect (i.e., the dominant hand reacting faster for positive stimuli and the non-dominant hand reacting faster for negative stimuli) was further confirmed by a follow-up study (de la Vega et al., 2013). This study allowed for the distinction between the hand effect per se and spatial factors, such as the locations of keys on the keyboard, which were confounded in the precedent study (de la Vega et al., 2012). Specifically, in de la Vega et al. (2013), two experiments were conducted employing an incongruent hand–response key assignment, where participants had their hands crossed. They were instructed to respond with their right vs left hand (Experiment 1) or with the right vs left key on a keyboard (Experiment 2). In both experiments, a compatibility effect related to the hand emerged, suggesting that the association between hand and valence took precedence over the one between side and valence when conflicting information is presented by the hand and side.

These findings were confirmed in a study conducted by Kong et al. (2013), in which the primary objective of the study was to examine the connections between the emotional valence of words or faces and manual responses in individuals with left- and right-handed preferences. The authors utilized a divided output (bimanual) response time paradigm, requiring participants to discriminate the emotional valence of words or faces presented at the center of the screen. Results showed that right-handed individuals exhibited faster responses when using their right hand for positive words or faces and their left hand for negative words or faces. Conversely, left-handed participants demonstrated the opposite pattern. As argued by the authors, these results further suggested that the relationship between spatial orientation and emotional valence is contingent on handedness, offering additional support for the BSH.

Similarly, de la Vega et al. (2015) explored whether a response facilitation could be identified when employing foot responses. Participants, predominantly right-footed (as indicated by a high score on a 5-item ad hoc footedness scale), were tasked with categorizing positive and negative words based on valence using keys pressed with their left or right foot. The analysis revealed a significant interaction between valence and foot, particularly evident in the by-items analysis. Specifically, when participants were categorized into two groups based on the strength of their right-footedness, a noteworthy interaction between valence and left/right emerged within the subset of strong right-footers. This subgroup demonstrated quicker responses with the right foot for positive words and with the left foot for negative words. Notably, no such interaction was observed among weak right-footers.

In summary, all these findings collectively emphasize the intracorporal origin of the BSH. The consistent valence-by-Left/Right interaction (i.e., hand/foot-compatibility effect) suggests that the hand prevails over the side, reinforcing the notion that the hand is a crucial factor in the development of body-specific associations. Notably, it was only in the follow-up study by de la Vega et al. (2013) that the hand compatibility effect was directly tested against the space side effect, revealing that the hand overrides the side when conveying conflicting information.

Furthermore, beyond this hand connotation effect, a study by Milhau et al. (2015) revealed a more nuanced understanding of hand-compatibility effects. In their study, Milhau et al. (2015)

identified the critical determinant as the response hand, shaping the participants' space-valence associations within the situational constraints of the task. In a valence judgment task with positive and negative words, both right-handers (Experiment 1) and left-handers (Experiment 2) used lateralized actions with their dominant or non-dominant hand, pressing lateralized buttons. Response devices were manipulated to create right-handers' associations (positive on the right side and negative on the left) and left-handers' associations (positive on the left side and negative on the right). The primary outcome revealed altered compatibility effects based on the hand used for responses. Right-handed participants using their dominant hand with a device congruent with their space-valence associations demonstrated faster evaluations of positive images than negative ones. Conversely, incongruent devices led to faster evaluations of negative images than positive ones. However, when using their non-dominant hand, right-handed participants evaluated positive words faster than negative ones with an incongruent device, while with a congruent device, they evaluated negative images faster. These results underscored compatibility effects between valence and side (ipsilateral actions) in unimanual response movements through congruent and incongruent devices. Interestingly, similar results were found in left-handed participants (Experiment 2). Unlike other studies, Milhau et al. (2015) identified an ipsilateral facilitation effect related to the direction of the movement, irrespective of handedness.

3.4 The impact of body specificity on emotional evaluation

It’s worth noticing that preceding the BSH, (Casasanto, 2009) antecedent investigations had already unveiled certain linkages between spatial orientation and affective valence. For example, in a valence judgement task, (Natale et al., 1983) right-handed individuals evaluated facial expressions as more negative when those expressions were presented in the left visual field. Instead, in a study by Everhart et al. (1996), while right-handed subjects' perceptions of neutral faces remained consistent across visual fields, left-handed individuals evaluated neutral faces as more positive (happy) when those stimuli were presented in the left visual field and negative (angry) when presented to the right visual field.

In this vein, recent studies investigating the influence of action (fluency) on emotional evaluation have revealed some changes in valence for stimuli. In the study by Milhau et al. (2013), during a valence judgment task, right-handed individuals executing fluent rightward arm movements using an evaluative scale congruent with their space-valence association (a scale where positivity was associated with the right and negativity with the left) tended to provide a positive evaluation for neutral words. Conversely, non-fluent leftward movements and an incongruent scale led to a negative evaluation.

In a study by Cervera Torres et al. (2020), participants engaged in a task that required direct contact with affective objects (pictures) through hand movements. Specifically, they interacted with the pictures using either their dominant right hand or their non-dominant left hand, involving movements from left to right or from right to left on a large touchscreen monitor (23 inches). Right-handed participants were then asked to evaluate the valence degree of positive and negative pictures after interacting with them. The authors reported a reinforcing effect on the valence appraisals of the pictures when there was a match between the valence category of the stimuli, the hand used for interaction, and the starting side of the movement. Specifically, this effect became apparent when (1) the stimuli were moved using the hand that matched the valence category of the pictures (e.g., positive pictures with the dominant hand and negative pictures with the non-dominant hand), and (2) when the starting side of the hand movement matched with these latter elements (e.g., the right hand moving positive images from right to left and vice versa for negative images).

In light of these findings, it may be worthwhile to investigate body-specific associations in environments that replicate real-world scenarios, as this could offer valuable insights. Specifically, it is essential to determine whether body specific associations observed in studies extend to everyday *digital* gestures, such as the *swipe* gesture. The act of swiping has become prevalent in our engagements with digital touchscreen interfaces, especially on small to medium-sized devices, and has developed specific connotations over time. This gestural language, deeply integrated into our digital interactions, introduces a nuanced communication medium. Here, swiping left on a stimulus signifies rejection, embodying a negatively laden concept, while, conversely, swiping right conveys potential interest, representing a positively laden concept within this established digital language.

Moreover, by directly investigating swipe gestures, we may address lingering questions raised by previous experiments, particularly the observation that the effects discovered seem to be short-term in nature. Hence, a pertinent question arises regarding the resilience of the BSH to cultural influences. It prompts us to ponder whether these relatively "new" gestures, such as swiping, have indeed transformed our perception and interaction with the digital world.

In addition, we think it would be crucial to disentangle extra-intra corporeal manifestations of body-specific associations. We will endeavor to address these questions through the following empirical studies (Experiment I with right-handed and Experiment II with left-handed participants) outlined in the subsequent chapter.

PART II: Empirical Studies

4. Experiment I - Exploring the body specificity hypothesis through swipe gestures: a response time paradigm on a mobile touchscreen device in right-handed participants

4.1 Introduction

Many cultures associate the abstract concepts of “good” and “bad” with specific spatial locations, where the right is typically associated with good and the left with bad (McManus, 2002).

This is reflected in idioms and words in many languages, where positive entities are generally associated with the right side and negative ones with the left side. As an example, in the English language right does not only represent a direction but also means correct; as well as the expression “to have two left feet” is used to talk about people very clumsy. However, according to BSH (Casasanto, 2009), beyond linguistic and cultural uses, people also implicitly associate good and bad things depending on handedness or, more precisely, on the (motor) fluency of the hands and feet (e.g. Casasanto, 2009; de la Vega et al., 2015).

In this vein, in line with the grounded cognition approach (Barsalou, 1999, 2008) as extensively discussed in the third chapter, Casasanto (2009) proposed the BSH. This hypothesis posits that right-handers and left-handers tend to associate “good” concepts with the space surrounding the dominant hand and “bad” concepts with the space surrounding the non-dominant hand.

Within the EC framework, these spontaneous associations are explained by referencing people’s diverse motor fluency experiences (e.g., the ease of performing an action): actions performed with the dominant hand are perceived as easier and more fluent, and, in turn, greater fluency is associated with positive affect (Beilock & Holt, 2007; Cannon et al., 2010).

In the context of the BSH, the relationship between fluency and positive affect appears to extend beyond fluency itself to the side associated with fluency, thereby establishing a connection between side and valence (i.e., space-valence association). This link is modulated by handedness.

In the first study investigating space-valence associations with handedness (Casasanto, 2009), participants with different handedness were tasked with the “Bob goes to the zoo” task. This task involved placing “good” and “bad” animals in two squares positioned on the right and left side of a piece of paper, either by drawing items or orally. The results showed opposing responses based on handedness: right-handed participants tended to place “good” animals on the right and “bad” animals on the left, while left-handed participants showed the opposite pattern (Casasanto, 2009, Experiments 1 and 3, detailed in Chapter 3).

Furthermore, in Experiment 4 of the same study, participants faced two alien creatures placed on either side of a paper. They tended to choose the creature situated on their dominant side as the most intelligent, funny, or honest. It is important to note that “dominant side” here refers to the participant's dominant hand (Casasanto, 2009). Such spontaneous space-valence associations have been shown to be robust, as they have been confirmed in children as young as 5 years old and in various cultures (de la Fuente et al., 2015).

Support for the BSH has been documented also across a range of contexts and tasks. For instance, studies measuring response times (de la Vega et al., 2012; Kong, 2013), as well as real-life simulations like job interviews and product selection, social evaluations such as dating decisions (Casasanto, 2009, Experiment 5), and even politicians' gestures during speeches, (Casasanto & Jasmin, 2010), have further underscored the phenomenon of body-specificity.

However, Casasanto & Chrysikou (2011) rigorously questioned the adaptability of these associations over time. Since these associations are deeply rooted in the motor fluency experienced during interactions with the environment, the hypothesis postulated was that any variations or changes in motor fluency could lead to alterations in the conceptualization of valence. To rigorously test this hypothesis, they intentionally manipulated hand fluency in a motor task involving dominos.

In their study, both right- and left-handed participants engaged in dominos manipulation using both hands while wearing a bulky ski glove on either their dominant or non-dominant hand to deliberately reduce fluency. Shortly after this motor task, participants underwent the oral version of the association task (the "Bob goes to the zoo task"). Results for participants wearing the glove on their non-dominant hands replicated Casasanto's (2009) findings. Notably, those wearing the glove on their dominant hand exhibited a reversed pattern. Right-handers tended to place positive items on the left side and negative items on the right side, mirroring the typical pattern of left-handers. Conversely, left-handers displayed the typical pattern of right-handers.

The findings, as argued by the authors, support the notion that the BSH is flexible, indicating that variations in how individuals execute actions with their bodies lead to corresponding variations in the conceptualization of the abstract notion of valence. Further evidence for the flexibility of the BSH comes from a study involving individuals recovering from stroke. In this study, right-handed individuals who lost the use of their dominant hand, when administered the "Bob goes to the zoo task," began associating the "good animals" with the left side (Casasanto & Chrysikou, 2011).

Furthermore, as mentioned above, the influence of action (i.e., fluency) on affect (i.e., valence) has been explored in various response time paradigms involving valence judgment tasks (de la Vega et al., 2012; Milhau et al., 2013, 2015). Specifically, a study by de la Vega et al. (2012) showed that processing valence-laden words facilitated compatible motor responses of the dominant or non-dominant hand (i.e., hand compatibility effect). This effect was also found in left-handed participants, who showed the opposite pattern of behavior compared to that of right-handers.

Similar results were found in the Kong et al. (2013) study where right-handed individuals exhibited faster responses when using their right hand for positive words or faces and their left hand for negative words or faces. Conversely, left-handed participants demonstrated the opposite pattern. Similarly, individuals favoring their right foot exhibit faster response time with their right foot in response to positive stimuli, and slower response time with their left foot to negative stimuli, indicating a specific bodily inclination within this cohort (de la Vega et al., 2015).

In addition, the hand compatibility effect (i.e., dominant hand reacts faster for positive stimuli and the non-dominant hand reacts faster for negative stimuli) was further confirmed by a follow up-study (de la Vega et al., 2013) which allows for distinguishing between hand effect per se and side, factors that were confounded in the preceding study (de la Vega et al., 2012). These findings, as argued by authors, address the intracorporeal origins of the BSH.

Nevertheless, beyond this hand connotation effect, a study by Milhau et al. (2015) revealed a more nuanced understanding of valence-compatibility effects. The authors proposed that motor fluency, defined as the experience of ease and/or rapidity associated with an action, prioritizes ipsilateral actions over contralateral ones, irrespective of handedness. This proposition is rooted in classic studies on aim-pointing tasks, demonstrating that ipsilateral actions are executed more easily and quickly than contralateral ones for both the dominant and non-dominant hand (Elliott et al., 1993; Hodges et al., 1997). In their study Milhau et al. (2015), identified the critical determinant as the response hand, shaping the participants' space-valence associations within the situational constraints of the task. In a valence judgment task with positive and negative words, both right-handers (Experiment 1) and left-handers (Experiment 2) responded with lateralized actions using either their dominant or non-dominant hand by pressing lateralized bottoms. The position of each response was manipulated creating a right-handers’ associations response device (positive on the right side and negative on the left) and a left-handers associations response device (positive on the left side and negative on the right).

Notably, the primary outcome of this study was the alteration of compatibility effects among participants based on the hand used for responses. Specifically, when right-handed participants utilized their dominant hand with a device congruent with their space-valence associations (linking positive valence with the right and negative valence with the left), they demonstrated faster evaluations of positive images than negative ones. Conversely, when using a device incongruent with their space-valence associations (linking positive valence with the left and negative valence with the right) negative images were evaluated faster than positive ones.

However, when right-handed participants used their non-dominant hand, they evaluated positive words faster than negative ones when the response device was incongruent with their space-valence association; while when the response device was congruent, they evaluated negative images faster.

These results, as suggested by the authors, underscored compatibility effects between valence and side (ipsilateral actions) in unimanual response movements through a congruent and incongruent response device. Similar results were found in left-handed participants. In other words, differently from all the other authors, Milhau et al. (2015) identified an ipsilateral facilitation effect related to the direction of the movement. In their findings, right-handers exhibited faster responses with their non-dominant left hand when the requested movement was toward the left, and with their dominant right hand when the requested movement was toward the right, irrespective of stimuli valence.

In addition, a study by the same authors (Milhau et al., 2017) further confirmed this association in a perceptual bisection task where emotionally positive words induced mental simulation of fluent lateral movements compared with negative and neutral words.

Based on these results, one might affirm that body-specific associations may be alternatively explained by (1) congruency between valence and side (Casasanto, 2009); or (2) compatibility between stimuli and both the dominant and non-dominant hand (de la Vega et al., 2013); or (3) linked with the interactions between the responding hand and side in a congruent and incongruent device (Milhau et al. 2015).

Furthermore, there is evidence suggesting that body-specific associations can impact explicit judgments of items. In this context, valence reinforcement effects for stimuli (i.e., stimuli being more positively/negatively evaluated) have been identified in a few studies involving a valence judgment task. These studies utilized facial expressions (Natale et al., 1983) and neutral faces (Everhart et al., 1996) as stimuli, presented on the side corresponding to the dominant or non-dominant hands of participants, where "corresponding" indicates the side aligned with the participants' dominant or non-dominant hand.

Several studies have demonstrated the impact of lateralized movements on valence evaluation. For example, in a valence judgment task, right-handed individuals, following a fluent rightward arm movement (from a centered key on a keyboard to a key on the right side), tended to provide positive evaluations for neutral words. Conversely, after a non-fluent leftward movement, they offered negative evaluations. This pattern was consistently observed on a scale associating positivity with the right and negativity with the left (Milhau et al., 2013).

More recently, in a study by Cervera Torres et al. (2020), valence reinforcements were observed on large touchscreens. Participants were tasked with making direct contact with affective objects through hand movements. The interactions involved using either the dominant right hand or the non-dominant left hand to move pictures from left to right or right to left on a large 23-inch touchscreen monitor. The authors noted a valence reinforcement effect under specific conditions: (1) when participants moved stimuli using the hand that matched the valence category of the stimuli (e.g., positive pictures with the dominant hand and negative pictures with the non-dominant hand), and (2) when the starting side of the hand movement corresponded with these valence-specific elements (e.g., the right hand moving positive images from right to left and vice versa for negative images).

Research questions

In light of the bulk of evidence on BSH (i.e., Casasanto, 2009; de la Vega et al., 2012, 2013; Kong, 2013; Milhau et al., 2013, 2015, 2017) and, in particular, looking at the more recent findings on valence reinforcement effects found in the study by Cervera Torres et al. (2020) on a large touchscreen, it would be crucial to investigate whether body-specific associations might be evident through a response-time paradigm that involves a swipe gesture on a small (mobile) touchscreen device, such as a tablet or smartphone.

It's important to underscore that when we refer to body-specific association, we mean a multitude of effects that have been found over time and addressed in the preceding paragraphs, such as: 1) space-valence associations 2) hand-compatibility effects, 3) valence reinforcement effects 4) interaction effects between hand and side through a congruent and incongruent device.

The rationale for probing into these phenomena utilizing the swipe gesture is diverse.

Firstly, it is necessary to consider that many digital applications, in which the swipe gesture is embedded, are designed based on universal western cultural norms. This incorporates a sort of "digital language," where swiping left on a stimulus signifies rejection (a negatively laden concept), while swiping right indicates potential interest (a positively laden concept). At this point, the question arises: are body-specific associations susceptible to this prevalent "digital language" found in numerous applications (e.g., dating apps), to the extent that left-handed individuals might act like right-handed ("right is good")?

Secondly, the swipe gesture has the advantage of involving a *subtle* hand movement that does not necessarily cross the body's midline. This limited movement allows us to effectively isolate the hand (and finger) movement from the rest of the body. This contrasts with the study by Cervera Torres et al. (2020) study, where hands movements specifically crossed the body's midline.

Thirdly, it is crucial to recognize the role of active movement in shaping body-specific associations, whether these associations originate intra or extra-corporeally. Active movement can manifest in various forms, such as fluent hand movements (e.g., pressing a key on a keyboard) towards both dominant and non-dominant sides (de la Vega et al., 2012) or on a screen (as seen in Cervera Torres et al., 2020), and even foot movements in both dominant and non-dominant spaces (de la Vega et al., 2015). The evidence suggests that active movement significantly reinforces the body specificity effect, especially when executed in alignment or misalignment with individuals' space-valence associations. As detailed in the third chapter, this reinforcing effect of movement is noteworthy because it can lead to facilitation, resulting in quicker response times when moving in spaces consistent with our space-valence associations (de la Vega et al., 2012, 2013). This ultimately contributes to a reinforcement effect of valence, as observed in the study by Cervera Torres et al. (2020).

In light of these considerations, the research questions of this first study, therefore, are as follows:

1) Do space-valence associations manifest in swipe gestures, which typically carry inherent meanings?
2) If yes, considering that the specific connotations of the swipe gesture align with the space-valence associations of right-handers, (linking positive valence with the right and negative valence with the left), the question arises: would left-handers present space-valence association even in a task involving the swipe gesture? Do left-handers mirror the behavior of right-handers, or do their innate space-valence associations also come into play in this context?
3) Do hand-compatibility effects (i.e. hand-valence associations) manifest in the swipe gesture?
4) Do hand and side interact across a congruent and incongruent swipe gesture?

Expected results are as follows.

a) **Research questions 1 and 2: space valence- associations**.

We expect an interaction between space and valence, regardless of the hand used in the swipe gesture. Our hypothesis is that in a valence judgements task:

- right-handed participants will exhibit faster response time when swiping right for positive images and swiping left for negative images (congruent condition) aligning with right-handers' space-valence association.
- Conversely, we expect slower response times when swiping left for positive images and swiping right for negative images (incongruent condition), misaligning with right-handed space-valence associations.

Following this reasoning, for left-handed participants, we expect faster response times in swiping right for negative images and swiping left for positive images (congruent condition) aligning with left-handed space-valence association, and slower response times in the incongruent condition.

In addition, following the study by Cervera Torres et al. (2020), a valence reinforcement effect is anticipated in both right-handers and left-handers. In this scenario, positive and negative images are expected to be evaluated as more positive and more negative, respectively, in the congruent condition compared to the incongruent condition.

However, alternatively, left-handed individuals, adapting to a predominantly right-handed "digital" world, might develop an accommodation, particularly with their dominant left hand, aligning with right-handers' behavior in the swipe gesture. In this scenario, we could expect left-handed individuals associating "good" with the right and "bad" with the left side. In other words, In the context of the swipe gesture, where swiping right is generally considered a positive gesture and swiping left is a negative gesture, they might align with right-handed behavior, linking "good" with the right and "bad" with the left side.

b) Research question 3: interaction between hand and valence

We anticipate observing an interaction between hand and valence, known as the hand compatibility effect. Both right-handed and left-handed individuals are expected to exhibit faster responses for positive and negative stimuli, respectively, with both the dominant and non-dominant hands. Importantly, the emergence of an effect exclusively related to the space-valence interaction (as described in the first outcome) would suggest that the body-specific effect manifests solely as an extracorporeal phenomenon. Conversely, the emergence of an effect exclusively related to the hand and valence interaction (as described in the second outcome) would imply that the effect manifests solely as an intracorporeal phenomenon.

c) Research question 4: interaction between hand and side

We expect an interaction between hand and side, referred to as the hand-by-side interaction, shaped by the motor fluency of the responding hand, following the framework proposed by Milhau et al. (2015). In this scenario, for right-handed participants:

- when responding with their dominant hand in the congruent condition (linking positive valence to the right and negative valence to the left), positive images are expected to be evaluated faster than negative ones while in the incongruent condition (linking positive valence to the left and negative valence to the right), negative images are expected be evaluated faster than positive ones.
- when right-handed participants use their non-dominant hand, they are expected to evaluate positive images faster than negative ones in the incongruent condition and, in the congruent condition, negative images faster than positive ones. We anticipate mirror outcomes for left-handed participants.

To test these hypotheses, we conducted a valence judgment task using positively and negatively valence-laden images. Participants (right-handed in Experiment I and left-handed in Experiment II) were instructed to focus on the valence of the stimuli and then respond with a swipe gesture aligned with their own space-valence associations (congruent condition) or misaligned (incongruent condition) with them.

4.2 Method

Participants

A total of 30 healthy right-handed participants (22 females, M_{age} = 27.2, SD_{age} = 2,6) from the University of Milan-Bicocca took part in Experiment I as volunteers. All participants had normal or corrected to normal vision and were naive to the purpose of the experiment. Based on existing literature using a similar procedure (e.g. Kong, 2013), and on an a priori power analysis using the G*Power software (Faul et al., 2007), a sample size of N=30 participants was estimated to have 80% probability to detect a significant interaction (α=.05) with a medium effect size (r=.25) in a mixed model, following Cohen's guidelines (Cohen, 1977). All participants read and signed a consent form before data collection in accordance with the ethical standards of the Declaration of Helsinki (World Medical Association, 2013). Ethical approval for the study was granted by the Committee for Research Evaluation of the University of Milan-Bicocca (Protocol number RM.2022-544).

Design

The study employed a 2 x 2 x 2 within-subjects design, in which the experimental condition (congruent vs incongruent), hand (right vs left) and valence category of stimuli (positive vs negative) were the factors.

Apparatus and stimuli

A Samsung Galaxy Tab A8 tablet served as the display device for presenting stimuli. The touchscreen monitor (TM) on the tablet measuring 10,5 inches and featured a resolution of 1920x1200 pixels. The experiment was conducted using a native Android mobile app created by the BiCApP (Bicocca Center for Applied Psychology) using the "React Native" framework (Zammetti, 2018). This app, integrated with Qualtrics (https://www.qualtrics.com/), automatically recorded all users' sessions data in a non-interactive Qualtrics survey, with information represented through embedded fields.

In terms of stimuli, we assembled a set of stimuli comprising 80 images, all of uniform size and resolution (640 x 426), sourced from the high-quality, royalty-free image website "Pixabay" (https://pixabay.com/it/). This careful selection aimed to construct a specialized database encompassing three distinct themes: animals, human-made objects, and scenes. After this first stimulus selection, we conduct a manipulation check procedure to ensure that our stimuli represent our target (valence-laden) images.

Manipulation check

A manipulation check procedure was conducted to validate stimuli before proceeding with the primary data collection phase. In order to ensure that the selected images efficiently provoked the intended positive or negative response a total of 60 participants (34 females, M_{age} = 26.2, SD_{age} = 3,6) were recruited as volunteers to evaluate the stimuli. Importantly, the participants involved in the manipulation check procedure were distinct from those who underwent the main experimental protocol, ensuring a separation between the groups.

Participants were individually tested on a laptop and assigned a valence judgment task for each image presented at the center of a 15.6-inch monitor with a resolution of 1366 x 768 pixels. To indicate the corresponding valence (positive or negative), participants clicked in a designated box. Following this judgment, participants were then instructed to rate the intensity of their positive or negative response on a vertically oriented Likert scale, which consisted of small squares numbered from 1 to 5. Here, 1 represented "poorly positive/negative," and 5 represented "very positive/negative." Ratings were provided by participants clicking on the square corresponding to their intended evaluation. The results indicated high appropriateness ratings for the targeted emotions across the images. Specifically, 68% of the positive images (41 out of 60) were rated as positive by at least 80% of the sample, while 47% of the negative images (28 out of 60) were rated as negative by at least 80% of the sample. Consequently, we selected only the images that received unanimous positive or negative evaluations from 100% of our study sample, with valence evaluation scores ranging from 4 to 5. Following this criterion, we obtained 28 images, comprising 14 positively and 14 negatively laden images. This procedure ensured that the valence associated with each image used for the subsequent experimental phase aligned precisely with our intended testing parameters.

4.3 Procedure

Participants underwent individual testing in a valence judgment task, evaluating both positive and negative images across two separate sessions. In the initial session, they used their dominant right hand, and in the second session (after 48 hours), they employed their non-dominant left hand (the order of hands was counterbalanced across participants).

The testing environment involved participants seated at a desk, with a tablet device positioned at the center, aligned with their body midline. Participants were reminded of their option to interrupt the experiment at any time and informed about encountering two experimental conditions, which they would repeat with the other hand after a 48-hour interval. The option to take a break between conditions was also provided. After a concise introduction to the study and completion of informed consent procedures, including the provision of personal information such as age, gender, and educational level, the task commenced. Prior to starting the experimental task, handedness was tested using the Edinburgh Inventory (Oldfield, 1971) in Italian translation. Additionally, three ad-hoc items were included to screen and include participants who used mobile devices and applications daily. The experimenter clarified the experiment's scope at the end of the sessions, namely the exploration of space-valence associations in relation to handedness.

The task began with a brief training session before each condition, accompanied by verbal instructions featuring two images. Participants judged whether a single image was positive or negative by positioning their index finger at the estimated center and swiping accordingly to indicate valence judgments.

In the Congruent Condition, participants swiped right for positive stimuli and left for negative stimuli, aligning with right-handers' body-specific associations. In the Incongruent Condition, the swiping direction was reversed (Figure 1). Verbal instructions explicitly informed participants about the need to reverse the swipe direction between the two conditions. The order of the conditions was counterbalanced across participants to mitigate sequencing effects bias.

Immediately after completing the valence judgment task, the displayed picture disappeared, and participants were prompted to rate the intensity of their positive or negative response. This rating was performed using a vertically oriented Likert scale, comprising small squares numbered from 1 (poorly positive/negative) to 9 (very positive/negative). Participants provided their ratings by touching the square that corresponded to their intended evaluation.

Following the Valence Evaluation (VE), a countdown from 3 to 1 preceded the presentation of a new image for evaluation. Each experimental session had a duration of approximately 10 minutes. Response time (RT) was measured from the onset of the image until the participant swiped either right or left. Valence evaluation (VE) for each image served as the dependent variable. In total, each participant underwent 112 different trials (14 positive and 14 negative images × 2 different response hands × 2 conditions, i.e., congruent vs incongruent).

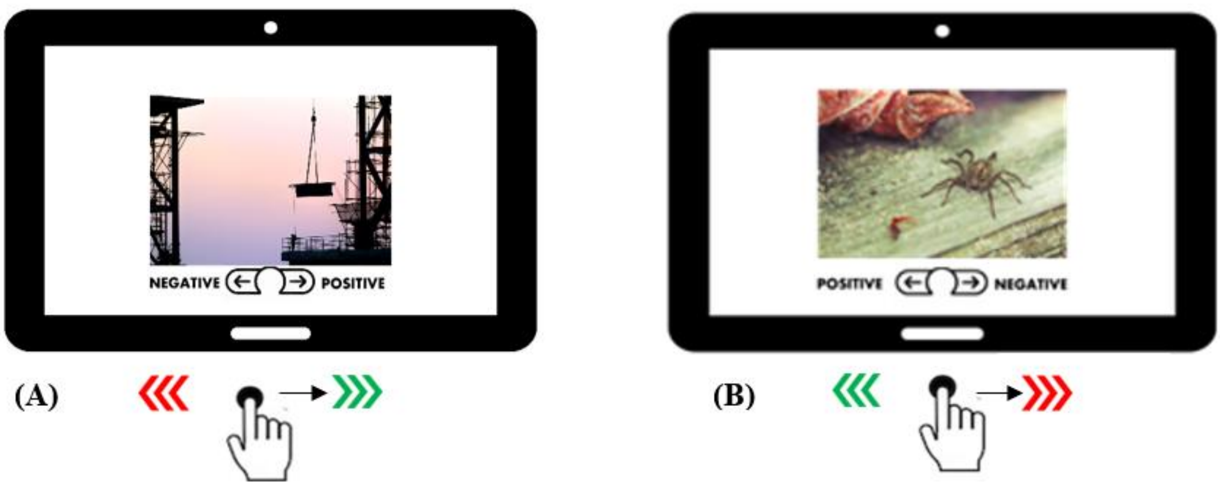

Figure 1. Participants underwent the Congruent Condition **(Panel A)** in which they swiped right for positive images and left for negative images, and the Incongruent Condition **(Panel B)** where they swiped left for positive images and right for negative images. The order of conditions was counterbalanced across participants.

4.4 Statistical analysis

Data were analyzed using two linear mixed effects model (LMM), one for RT and one for VE, with the software Jamovi, version 2.3 (*The Jamovi Project*, 2023). All statistical tests were conducted on a two-tailed .05 level of significance. To select an appropriate random component, we started setting all plausible effects as random. The model with the intercept, valence and condition as random coefficients was the one that converged.

Thus, the final model included a random intercept across participants, with experimental Condition (congruent vs incongruent) and Valence (positive vs negative) as random factors, along with their interaction. Hand (right vs left hand) was included as fixed factors. To calculate p values estimates for the fixed effects, it was used a Type III Satterthwaite approximation (e.g., Carr et al., 2016). For RT, only response times corresponding to correct answers were preserved in the statistical analysis, leading to the exclusion of 13% of data. RT greater or less than 2SDs of the subject average in each experimental group were excluded from final analyses (7%).

4.5 Results

Response Time

A main effect of Condition $F(1,23) = 6.57$, $p = .01$ showed that the specific experimental condition had a significant influence on participants' swiping behavior (Figure 2). Specifically, right-handed participants were faster in swiping right for positive images and swiping left for negative images (Congruent Condition) as compared with the opposite condition (Incongruent Condition). As one might expect, a main effect of Hand emerged, $F(1,1459) = 14.80$, $p < .001$ with higher RT for the non-dominant left hand. Interestingly, a significant interaction between Hand and Valence emerged $F(1,459) = 149.82$, $p < .001$. Specifically, right-handed individuals exhibited lower RT when swiping for negative images with the non-dominant left hand (as compared to positive images), regardless of the Conditions (Figure 3, Table 1). The interactions between Valence and Condition, $F(1,4529) = 0.06$, $p = .81$ and Hand and Condition, $F(1,4529) = 1.46$, p

=.22 were not significant, indicating that the combined influence of these factors did not significantly affect participants' responses. The three-way interactions between Valence, Hand, and Condition were not significant either $F(1,4529) = 0{,}44$, $p = .50$ indicating that the combined influence of all three factors did not significantly impact participants' responses.

Effects plots

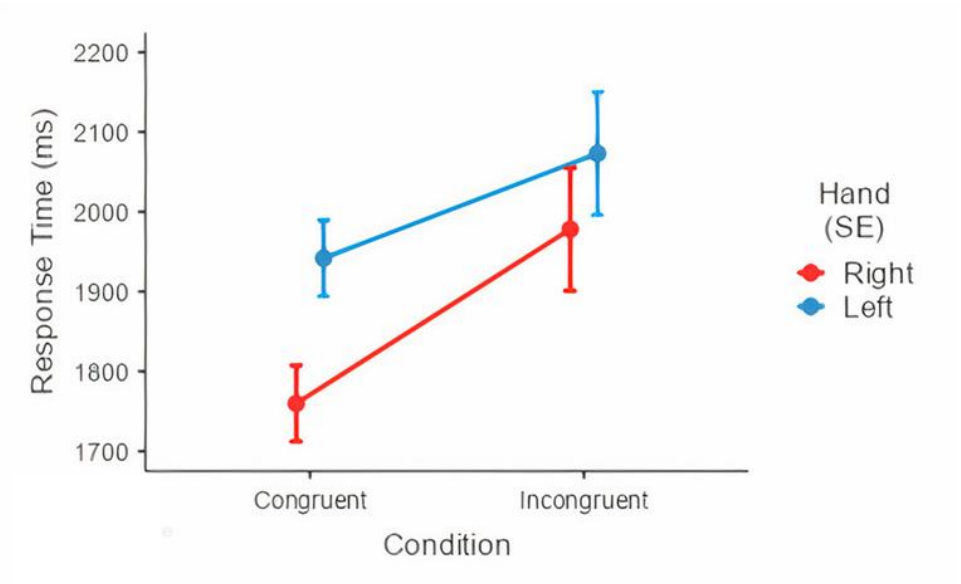

Figure 2. RTs as a function of Condition. Red line indicates the right dominant hand, and the blue line the left non-dominant hand. RTs are higher in the IC compared with the CC (p =.01). Error bars indicates Standard Errors (SE).

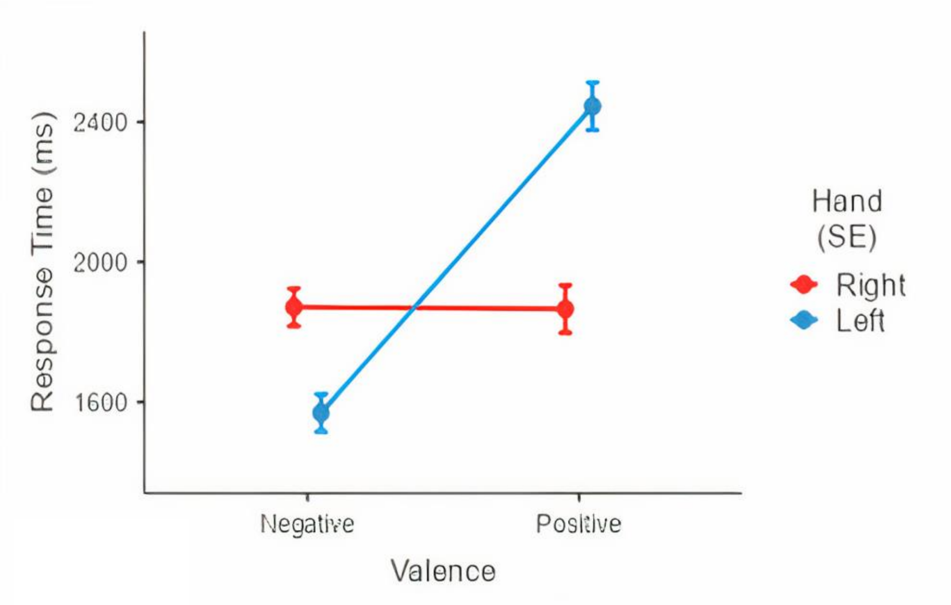

Figure 3. RTs as function of Valence and Hand. Red line indicates the right-dominant hand, and the blue line the non-dominant left hand. RTs are lower for the non-dominant left hand when interacting with negative stimuli compared with positive ones (p <.001). Error bars indicating Standard Errors (SE)

Simple Effects analysis

To gain a more detailed understanding of Valence a simple effects analysis was conducted, with Hand as a moderator (Right vs Left). The analysis revealed a non-significant effect for the right dominant hand, $F(1,44.7) = 0.007$, $p = .93$, indicating that, under this condition, the valence of stimuli did not significantly impact participants' responses. Conversely, a highly significant effect was observed for the left non-dominant hand, $F(1,44.7)= 167.84$, $p < .001$). This suggests that, when utilizing their left hand, participants' responses were notably influenced by the valence of stimuli (Table 1).

Simple effects of Valence: Omnibus Tests

Moderator levels				
Hand	**F**	**Num df**	**Den df**	**p**
Right	0.00700	1.00	44.7	0.934
Left	167.84600	1.00	44.7	< .001

Table 1

Valence evaluation

A main effect of Valence $F(1,23) = 9,74$, $p < .01$) was found with higher evaluation for negative images than positive images. The factor Hand did not yield a significant effect $F(1,2611) = 0.02$, $p = .89$, suggesting that the choice of hand used during the task did not substantially influence participants' responses. Similarly, the factor Condition did not exhibit a significant effect $F(1,23)= 0.04$, $p = .84$, indicating that the specific experimental condition did not significantly impact participants' VE. Additionally, we found no significant effects for the two-way interactions between Valence and Hand, $F(1,2634) = 0.54$, $p < .46$) and Valence and Condition $F(1,2634) = 0,01$, $p = .89$.

However, there was a marginally significant interaction effect between Condition and Hand, $F(1,2611) = 3.17$, $p = .07$. This suggests that there may be a nuanced relationship between the choice of hand and the experimental condition, warranting further investigation. Lastly, the three-way interactions between Valence Category, Hand, and Condition were not significant too $F(1,2634) = 0.11$, $p = .74$).

4.6 Discussion

In Experiment I, our primary aim was to investigate the BSH in a real-world scenario in right-handed participants, utilizing a swipe gesture on a tablet device. The initial hypothesis was that aligning participants' space-valence associations with the swipe response type, making it congruent with their inherent space-valence associations, would facilitate valence judgments.

In other words, irrespective of the hands used, as a first outcome, we expected lower response times for both positive and negative images when the swipe gesture aligned with participants' space-valence associations (i.e. swipe right for positive, swipe left for negative, congruent condition) compared to an incongruent swipe pattern (i.e. swipe left for positive, swipe right for negative, incongruent condition).

The results confirmed these predictions, revealing faster evaluations for both positive and negative stimuli in the congruent swipe pattern and slower evaluations for both positive and negative stimuli in the incongruent swipe pattern.

These findings reinforced the extracorporeal origin of the BSH observed in prior studies, emphasizing the space-valence association (Casasanto, 2009) which refer to compatibility between valence images and the space where images were moved through the swipe gesture.

As a secondary goal, we aimed to explore hand-compatibility effects. Interestingly, our study revealed that right-handed participants were faster when swiping for negative images with the non-dominant left hand, regardless of swipe gesture congruency. This finding is quite surprising, as the non-dominant hand demonstrated even faster responses than the dominant one when dealing with negative stimuli.

These findings are consistent with existing studies on BSH, which have identified intracorporeal origins of body-specific associations between left/right hand and stimuli valence. Interestingly, hand-compatibility effects (i.e. hand-valence associations) were previously noted only with valence-laden words (de la Vega et al., 2012) and facial expressions as stimuli (Kong et al., 2013). In this context, Experiment I represents the first demonstration of both space-valence and hand-valence associations using the swipe gesture on a mobile touchscreen device.

Notably, as aforementioned, right-handed individuals demonstrate hand-valence associations exclusively with their non-dominant left hand for negative stimuli, responding even faster than with their dominant right hand. We hypothesize that this result could be attributed to the continuous interaction with digital devices (and mobile applications), which may have a more pronounced impact on the dominant right hand, while the non-dominant left hand is more influenced by the hand-valence associations.

Nevertheless, valence reinforcement effects were not observed in our study. Several factors may contribute to this absence.

Firstly, unlike the Milhau et al. (2013) study where a valence reinforcement effect was noted, we employed a one-dimensional vertically oriented Likert scale ranging from 1 to 9. This deliberate design aimed to avoid congruent or incongruent scale effects with participants' space-valence associations. In the Milhau et al. (2013) study, the valence reinforcement effect was observed only when the numerical scale aligned congruently with the space-valence mapping for right-handers.

Secondly, in a study demonstrating valence reinforcement effects (Cervera Torres et al., 2020), these effects were observed only under specific conditions involving a match between (a) the hand used for interaction, (b) the valence category of pictures, and (c) the starting side of the movement. The larger interface with extensive hand and arm movements likely contributed to the observed effect. Lastly, it is possible that the dimensions of our device (10.5 inches) compared with those of Cervera Torres et al. (2020) study (23-inch) may have played a role.

Furthermore, contrary to our expectations, we did not observe an interaction between hand and side (i.e., hand-by-side interactions), as demonstrated in the Milhau et al. (2015) study. In this scenario, for right-handers responding with their dominant hand in the congruent condition, we expected positive evaluations to be faster than negative ones. Conversely, in the incongruent condition, we anticipated negative images to be evaluated faster than positive ones. Similarly, for right-handers responding with their non-dominant hand, positive images were expected to be evaluated faster in the incongruent condition, while negative images were expected to be evaluated faster in the congruent condition.

The reason for not observing this result is evident. Regardless of the hands used, we consistently observed a preference for congruent responses (linking positive valence with the right and negative valence with the left) over incongruent ones (linking positive valence with the left and negative valence with the right). Consequently, capturing the hand-by-side interaction, as identified in the Milhau et al. (2015) study, proved impossible. Notably, the study by Cervera Torres et al. (2020) also failed to uncover a comparable effect and was conducted on touchscreen surfaces, similar to our Experiment I.

Conclusion

In summary, these preliminary findings highlight interaction effects between valence and space (i.e., space-valence associations) in unimanual response movements, such as the swipe gesture, along with interactions between hand and stimuli (i.e., hand-compatibility effects). It's noteworthy that the observed space-valence associations align with expectations for right-handers, as their spatial-valence associations correspond with prevalent mobile app design (e.g., dating apps). In these designs, swiping left typically signifies rejection (a negatively charged concept), while swiping right indicates potential interest (a positively charged concept).

The intriguing question now revolves around left-handed individuals. Will they exhibit similar behavior to right-handed participants, associating the right with the positive and the left with the negative? Alternatively, will their natural space-valence associations come into play? To address this, we conducted a replication of Experiment I with left-handed participants.

5. Experiment II - Exploring the body specificity hypothesis through swipe gestures: a response time paradigm on a mobile touchscreen device in left-handed participants

5.1 Introduction

In Experiment I, performance differences were revealed in a valence judgment task based on the congruency of responses through a swipe gesture. The key finding highlighted that, regardless of the hand engaged in the swipe gesture, right-handed participants demonstrated an implicit preference (i.e., facilitation effect) for swiping right for positive images and swiping left for negative ones (congruent condition) compared to the opposite pattern (incongruent condition, swipe right for negative images, swipe left for positive images). This response pattern aligns with the natural space-valence associations of right-handed individuals, associating the right space with positivity and the left space with negativity.

Importantly, the observed set-up in Experiment I mirrors the design of numerous mobile apps, where a left swipe gesture commonly signifies rejection (linked with a negative concept), while a right swipe gesture suggests potential interest (associated with a positive concept).

In Experiment II, our objective is to replicate the outcomes of Experiment I within a population of left-handers. Specifically, our primary goal is to address research question 2, as detailed in the "Research question" paragraph in Experiment I. This question can be summarized as follows: should left-handers achieve performances comparable to those of right-handers, displaying shorter response times for both positive and negative evaluations in alignment with their own space-valence associations (i.e., associating left with positive images and right with negative images)?

Alternatively, considering the pervasive use of mobile devices and applications in a predominantly right-handed digital world, might left-handers adapt their behavior to align with the "Right is Good" trend observed in right-handers?

However, it is also possible that left-handed individuals, adapting to a predominantly right-handed digital world, might develop an accommodation, showing a performance that falls somewhere between their spontaneous preference (i.e., left is positive; right is negative) and the "right-handed world" in which they live (where the association is right-positive and left-negative).

To clarify this point, we replicated the Experiment I with left-handed individuals. Research questions, as mentioned earlier, were identical to those in Experiment I, as well as the study design which employed a 2 x 2 x 2 within-subjects design. The factors considered were the experimental Condition (congruent vs incongruent), Hand (right vs left), and Valence Category of stimuli (positive vs negative). Like Experiment I, response time (RT) and valence evaluation (VE) serves as our dependent variables.

5.2 Method

Participants

A total of 30 left-handed participants (13 females, M_{age} = 26.6, SD_{age} = 3,01) from the University of Milan-Bicocca took part in Experiment II as volunteers. As for Experiment I, based on existing literature using a similar procedure (e.g. Kong, 2013), and on an a priori power analysis using the G*Power software (Faul et al., 2007), a sample size of N=30 participants was estimated to have 80% probability to detect a significant interaction (α=.05) with a medium effect size (r=.25) in a mixed model, following Cohen's guidelines (Cohen, 1977). All participants read and signed a consent form prior to data collection in accordance with the Declaration of Helsinki (World Medical Association, 2013). Ethical approval for the study was received by the Committee for Research Evaluation of the University of Milan-Bicocca (Protocol number: RM.2022-544).

Design

The study design was the same employed in Experiment I.

Apparatus and stimuli

The materials were the same as those employed in Experiment I.

5.3 Procedure

The procedure mirrored that of Experiment I

5.4 Statistical analysis

The data were analyzed using two linear mixed-effects models (LMM) in Jamovi, version 2.3 (The Jamovi Project, 2023). All statistical tests were conducted at a two-tailed .05 level of significance. For response time (RT) data, we initially considered all plausible effects as random components. The model that converged included the intercept, valence, condition, and hand as random coefficients. Consequently, the final model had the intercept across participants and all main effects as random coefficients, while their interaction was treated as fixed factors. Only RT data corresponding to correct answers were retained for statistical analysis, resulting in the exclusion of 5% of the data. Additionally, RT values greater or less than 2 standard deviations (SDs) from the subject average in each experimental group were excluded from further analyses, accounting for 8% of the data.

For the valence evaluation (VE) data, a model with the intercept, valence, and conditions as random coefficients successfully converged. Consequently, the final model included the intercept across participants, valence, and conditions as random coefficients, while their interactions and hand were included as fixed coefficients.

5.5 Results

Response time

A significant main effect of Valence was found, indicating lower RT for positive images compared with negative ones, F (1,25) = 4.80, p = .03. Regardless of the experimental conditions, a significant main effect of Hand emerged with lower RT for the dominant left hand, F(1,25) = 21.24, p < .001. The analysis revealed also a non-significant effect for the Condition factor F (1,25)

= 1.030, *p* = .32, suggesting that differences between experimental conditions did not significantly contribute to the observed variability.

However, a significant interaction effect between Hand and Condition emerged *F*(1,2804) = 11.66, *p* <.001) denoting higher RTs for the right non-dominant hand in the incongruent condition compared with the congruent condition (Figure 4, Table 3).

Both the two-way interactions between Valence and Condition *F*(1,2804) = 0.16, *p* = .68, and Valence and Hand *F*(1,2804) = 2.16, *p* = .68, were not significant. The three-way interaction between Valence Category, Hand, and Condition was also not significant *F*(1,284) = 0.10, *p* = .74.

Effects plot

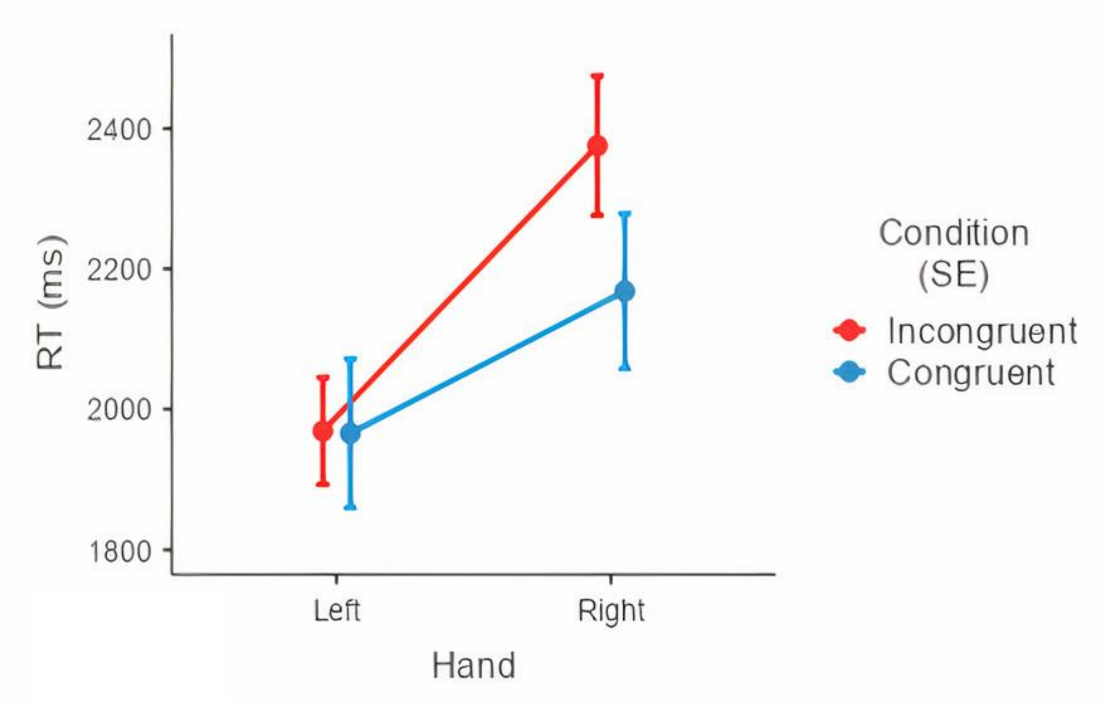

Figure 4 RTs as a function of Hand and Condition. Red line indicates Incongruent condition, and the blue line congruent. RTs are higher for the right non-dominant hand in the Incongruent Condition (p <.001). Error bars indicating Standard Errors (SE).

Simple effect analysis

To gain a more detailed understanding of the Condition factor, a simple effect analysis was conducted, with Hand serving as a moderator (Right vs Left). As depicted in Table 3, the significant interaction mainly arises from variations in RT between the two conditions when using the non-dominant right hand. In contrast, responses with the dominant left hand were nearly identical, as illustrated in Figure 4.

Simple effects of Condition: Parameter estimates

Moderator levels				**95% Confidence Interval**				
Hand	**contrast**	**Estimate**	**SE**	**Lower**	**Upper**	**df**	**t**	**p**
Left	Congruent - Incongruent	-3.33	44.2	-90.1	83.4	2829	0.0753	0.940
Right	Congruent - Incongruent	-207.21	44.2	-294.0	-120.5	2829	4.6833	< .001

Table 3

Valence evaluation

A significant main effect of Condition was found, indicating higher evaluation for both negative and positive images in the Congruent Condition compared with the Incongruent Condition, $F(1,25) = 7.41$, $p = .01$, (Figure 5). No statistically significant main effects were observed for Hand $F(1,2829) = 0.09$, $p = .76$ or Valence $F(1,25) = 0.03$, $p = .86$.

The interaction between Valence and Hand was also not statistically significant $F(1, 2879) = 0.66$, $p = .41$. The interaction between Valence and Conditions was similarly not significant $F(1,2879) = 1.42$, $p = .23$). Likewise, the interaction between Hand and Conditions was not significant, $F(1, 2879) = 1.05$, $p = .30$, suggesting that the relationship between Hand and VE did not significantly differ across experimental conditions. The three-way interaction was also not statistically significant $F(1, 2879) = 0.04$, $p = .841$.

Effects plot

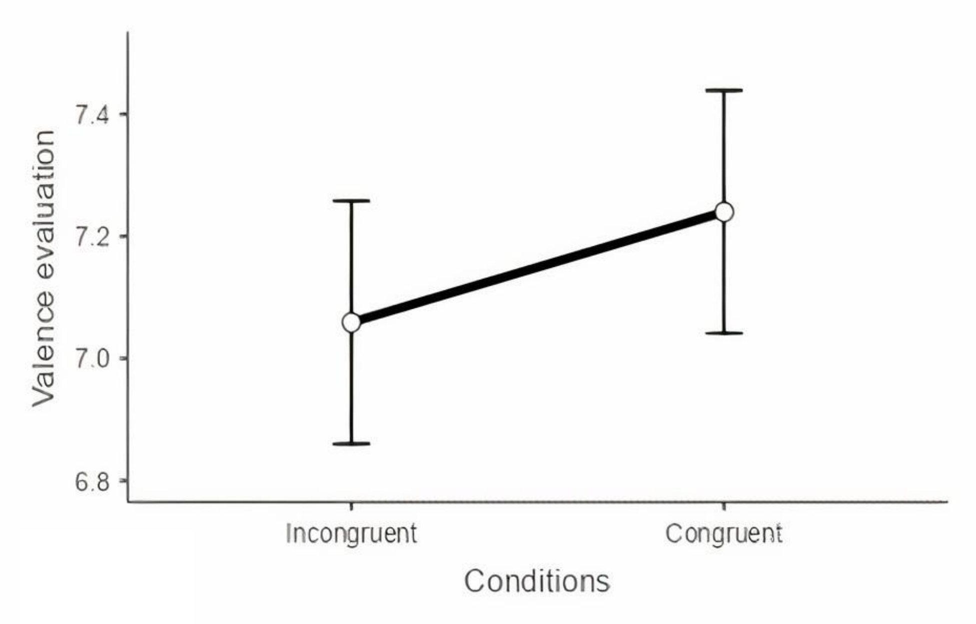

Figure 5 VE as a function of Conditions with higher VE in the Congruent condition compared to the Incongruent one (p=.01). Error bars indicating Standard Errors (SE).

5.6 Discussion

The results from Experiment II partially replicated the effects observed in Experiment I with right-handed individuals. Despite not observing any hand-compatibility effects, (i.e., hand-valence associations), we did find a significant interaction between Hand and Condition.

In particular, when left-handers used their non-dominant right hand, a preference for the congruent condition (i.e., swiping left for positive, swiping right for negative) emerged, resulting in lower response times in the congruent condition compared to the incongruent one. In essence, space-valence associations became evident only when left-handed participants utilized their non-dominant right hand. This led to the identification of a hand-by-condition interaction, resembling the expected hand-by-side interaction (Milhau et al., 2015), where the responding hand and the device (congruent vs incongruent) played crucial roles. However, contrary to the Milhau et al. (2015) study, our results demonstrated that when left-handers used their non-dominant right hand, they were quicker in swiping right for negative images and swiping left for positive images (i.e., congruent condition) compared to the opposite pattern, aligning with their inherent space-valence associations. Thus, space-valence associations did not manifest when left-handers used their dominant left hand.

We hypothesize that this partial insensitivity to the experimental manipulation may reflect the habit of left-handers primarily using their dominant left hand in both digital and real environments, which are typically designed for right-handers. Like real-world scenarios, we attribute our results to an implicit habituation effect in left-handers, who are more accustomed to navigating between right and left spaces than right-handed individuals.

As a result, it is reasonable to presume that left-handers exhibit greater flexibility in their interaction with the environment, given their constant exposure to a world predominantly designed for right-handers. Consistent with the suggestion by Milhau et al. (2015), left-handers may not develop negative (implicit) associations with conditions incongruent with their preferences (left-positive, right-negative), possibly due to their habit of encountering incongruent situations with their dominant hand.

Nevertheless, participants in our study consistently judged more positive and more negative images in the congruent condition and fewer positive and negative images in the incongruent condition (i.e., valence reinforcement effect), regardless of the hand used. Based on these findings, we could hypothesize that the habituation effect mentioned earlier is evident primarily at the implicit level, as reflected solely in response time data

Conclusion

In summary, these initial findings underscore the intricate interactions between space and valence in left-handed individuals, highlighting the pivotal role of the responding hand—specifically the right non-dominant hand—in the emergence of an implicit preference for swiping congruent with left-handed space-valence associations (i.e., swipe right for negative, swipe left for positive). Nevertheless, this preference diminishes when participants use their dominant left hand, indicating a developed flexibility over time in using the dominant left hand in both right and left spaces within a predominantly right-handed digital (and non-digital) world.

Notably, the observed reinforcement effect in valence evaluation provides further support for the BSH at the explicit cognitive level. In conclusion, considering the results, we assert that the greater flexibility observed in left-handers, compared to right-handers, accounts for a significant portion of the differences in results between the two groups. It is crucial to acknowledge, however, that despite left-handers exhibiting greater flexibility, they do not replicate the behavior of right-handers ("Right is Good"), as hypothesized. Instead, they appear to be insensitive to experimental manipulation when using their dominant left hand. This is particularly noteworthy given that our sample habitually uses mobile applications predominantly designed based on the space-valence associations of right-handers.

General discussion

The purpose of Experiment I and Experiment II was to contribute to the investigation of the BSH proposed by Casasanto (2009). Specifically, we explored space-valence associations in a valence judgments task involving lateral swipe gestures. Specifically, building upon previous research that examined valence reinforcements effects on a large touchscreen (Cervera Torres et al., 2020), we also collected response time data to obtain an implicit measure of space-valence associations and hand-valence associations.

In particular, for both experiments (Experiment I and Experiment II) participants performed a valence judgment task on images with positive and negative connotations, providing responses through a right/left swipe gesture, engaging one hand at a time (specifically the dominant and non-dominant hand). Moreover, beyond offering valence judgments, participants were tasked with assessing the valence levels of each image using a vertically oriented one-dimensional 9-point Likert scale.

We manipulated the direction of the positive and negative swipe responses in congruent and incongruent conditions based on participants' natural space-valence associations. Congruent condition aligned with space-valence associations of either right-handers or left-handers (right-handers' associations: swipe right for positive and swipe left for negative; left-handers' associations: swipe right for negative and swipe left for positive).

In the incongruent condition the response direction dissociated with participants space valence associations (i.e., for right-handed: swipe right for negative and swipe left for positive; for left-handed: swipe right for positive and swipe left for negative).

In line with the BSH proposed by Casasanto (2009), we anticipated divergent patterns for right-handed and left-handed participants. Specifically, we expected right-handed individuals to exhibit faster responses when swiping right for positive images and swiping left for negative images (congruent condition) compared to the opposite pattern (swiping right for negative, swiping left for positive, incongruent condition). Conversely, we anticipated the reverse pattern for left-handed participants.

Additionally, we considered an alternative hypothesis, contemplating the potential impact of space-valence associations in left-handed individuals influenced by extensive use of mobile applications, such as dating apps. In the digital realm, swiping right is commonly linked to a positive or forward action, while swiping left is associated with a negative or backward action. With this in mind, we speculated that left-handers might exhibit patterns of associations similar to those of right-handers, associating the right side with positive valence and the left side with negative valence. This led us to pose our primary research question: do space-valence associations manifest in swipe gestures, inherently linked to their own meaning (positive-is-right; negative-is-left)? If so, does left-handed performance mirror that of right-handers? Alternatively, do their inherent space-valence associations take precedence in this scenario?

To address these questions, we initially tested the swipe gesture on right-handed participants in Experiment I. The decision to examine the same questions in two distinct experiments (one for right-handed and one for left-handed participants) is primarily grounded in prior research on lateral hand movements on keyboards (de la Vega et al., 2012, 2013; Kong, 2013; Milhau et al., 2015). This literature highlighted two potentially critical factors: the fluency of hand responses and the specific locations of those responses. Milhau et al. (2015) underscored the importance of instructing participants to respond using only one hand at a time, differentiating between the hand used for the response and the side of the response—a distinction previously conflated in the works of de la Vega et al. (2012) and Kong (2013).

Subsequently, we conducted a replication of the task with left-handed participants (Experiment II), playing a crucial role in balancing the outcomes of this study.

Results indicated that right-handed participants were faster in swiping images congruently to their usual space-valence associations with both their dominant and non-dominant hands, while left-handed individuals exhibited this effect only with the non-dominant right hand. This suggests that for the emergence of space-valence association, the responding hand is crucial for left-handed, indicating greater adaptability in left-handers' interactions with the environment. Consequently, we may posit that left-handed inherently associate negative connotations with conditions that are congruent with their own established associations only when using their non-dominant hand. When using their dominant left hand, this association appears to be mitigated by their familiarity with experiencing incongruities with their dominant left hand.

However, it is important to emphasize that in left-handers individuals this adaptability occurs only at the implicit level. In fact, surprisingly, left-handed participants, unlike to their right-handed counterparts, showed significant differences in valence evaluations levels, with more positive and negative evaluation to positive and negative images in the congruent condition compared to the incongruent one, independently by the hands involved.

Another notable effect observed in right-handed participants (Experiment I), but not in left-handed ones (Experiment II), is the hand compatibility effect (i.e., hand-valence associations).

Specifically, right-handed individuals exhibited faster responses to negative images with their left hand compared to their right hand. Strikingly, this hand compatibility effect was not observed in left-handed participants. Considering these results, we can assert that for right-handers, body-specific associations manifest as both intra and extracorporeal phenomena, whereas in left-handers, these associations appear to be of an extracorporeal nature.

Furthermore, upon comparing the results of right-handed and left-handed individuals, our study highlights that left-handed individuals exhibit *space-valence* associations only with their non-dominant hand. In contrast, right-handed individuals demonstrate *hand-valence* associations, but again, only with their non-dominant hand, particularly for negative stimuli, where they even exhibit faster responses than with their dominant right hand.

These findings seem to convey three key insights:

a. Our experimental paradigm, involving interaction with a mobile touchscreen through the swipe gesture that does not cross the body's midline, reinforces body-specific associations more strongly compared to tasks that request associations on purely cognitive bases (e.g., association tasks or pressing a right key for positive and a left key for negative). In tasks of the latter type, even if the requested response is a motor one (such as pressing a key), the previous association is not simultaneous, whereas interacting with a touchscreen establishes concurrent associations between body, space, and action. Consequently, the literature's dichotomy between hand-valence associations and space-valence associations does not seem to provide a suitable framework for understanding our data.

b. Instead, our data are better explained by considering hand-valence and space-valence associations together.
c. Furthermore, both right-handed and left-handed individuals exhibit the most intriguing results when examining data related to the *non-dominant hand*, supporting our hypothesis that this hand undergoes less influence from continuous interaction with mobile applications/digital devices.

As mentioned earlier, in right-handed individuals, regardless of the conditions (congruent vs incongruent), we did not find hand-valence associations between the right-dominant hand and positive stimuli. Similarly, left-handed individuals did not exhibit space-valence associations when using their dominant left hand, indicating a form of desensitization to body-specific associations. This desensitization is evident when both left-handed and right-handed participants use their dominant hand. We hypothesize that this desensitization occurs because individuals, with their dominant hand, are significantly more accustomed to swiping right or left. In other words, space-valence associations appear weaker and less susceptible to experimental manipulation.

Taken together, we can assert that these findings support the BSH albeit with some influence from the continuous use of digital/app devices, which appears to have desensitized individuals, particularly when using the dominant hand.

Findings supporting the BSH can be traced through the space-valence and hand-valence associations observed in this study, which are not solely dependent on either the space or hand used for the response. This interplay becomes evident when examining the heterogeneity of our results. In Experiment I, it appears that space plays a more dominant role independently of the hands involved in the swipe gesture. However, a markedly different situation is evident in left-handers (Experiment II), where the hand plays a central role in transitioning between congruent and incongruent conditions.

Finally, both Experiment I and II possess inherent strengths and limitations. A notable strength lies in our adherence to the recommendation of Milhau et al. (2015), emphasizing the importance of the response device in valence judgment tasks. Our study marks the first demonstration of using a mobile touchscreen device that restricts movement across the body's midline, isolating hand and finger movements from the influence of the rest of the body—a factor that was confounding in the Cervera Torres et al. (2020) study. Furthermore, in a complex experimental design, other authors often opt to limit the investigation to one population only (either right- or left-handed), with Milhau et al. (2015) being the only exception. In this perspective, our study is the first to use a mobile touchscreen specifically to address the BSH. However, a limitation of Experiment I is that negative images were rated much more negatively than positive ones a priori, irrespective of the conditions (congruent vs incongruent). This highlights a significant difference in the absolute evaluation of negative and positive images, serving as a clear limitation of the study. In addition, this could also explain the absence of the valence reinforcement effect in right-handed individuals.

In conclusion, the findings of this study underscore how the direction of the swipe gesture influences participants' valence associations. It also highlights the impact and role of motor instructions provided to participants, such as responding with one hand at a time or using only the dominant or non-dominant hand. Hence, our research lends credence to the notion that emotional assessment arises from sensorimotor interactions within the environment, aligning with an embodied and context-dependent understanding of emotional evaluation (Leitan & Chaffey, 2014).

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6. Experiment III - Comparing space-valence associations with hand-valence associations in swipe gestures: a subsequent investigation

6.1 Introduction

In Experiment I we explored space-valence associations in a valence judgment task through a swipe gesture in right-handers individuals. The results supported the BSH since they preferred to swipe on the side of their right-dominant hand for positive images and to swipe on the side of their left-non dominant hand for negative images. Notably, we observed this preference independently by the hand involved for the swipe gesture.

Furthermore, right-handed individuals, unlike their left-handed counterparts (Experiment II), also showed an association related to the hand and valence representing an intracorporeal manifestation of BSH. Specifically, this association was based on the compatibility between their non-dominant left hand and negative images, termed as the hand-compatibility effect. To illustrate, right-handed participants were faster when using their non-dominant left hand to interact with negative images compared to positive ones, irrespective of the congruency or incongruency of conditions. In summary, Experiment I identified both a space-valence association (related to the extracorporeal space) and a hand-valence association effect (or hand-compatibility effect, related to the intracorporeal space). Consequently, considering these results, we can assert that these two associations can coexist as manifestations of the same phenomenon (the BSH), without one surpassing the other.

However, our results contrast with those of de la Vega et al. (2013), who reported that the association between hand and valence overrides the one between space and valence when hand and space carry contradicting information (e.g. when hand and side are dissociated). Specifically, the question posed by de la Vega et al. (2013) revolved around whether to consider body-specific associations as intra- or extra-corporeal space. Similar inquiries have been explored in various associations, such as the correlation between numbers and space, namely the SNARC effect (Dehaene et al., 1993).

The SNARC effect is a phenomenon in which humans typically respond faster to relatively small numbers (e.g., 1-4) with a left key, and faster to relatively large numbers (e.g., 6-9) with a right key, when numbers are centrally presented. It has been interpreted as evidence that humans mentally represent numbers from left to right according to a mental number line. The mechanisms underpinning this association are still debated (Casasanto & Pitt, 2019; Prpic et al., 2021).

Dehaene and colleagues (1993) addressed the question of whether this numerical-spatial association was tied to an individual's hand or to extracorporeal space. In their experiment, participants were asked to respond to small and large numbers with their hands crossed. The results revealed that responses to small numbers were still quicker with the left key (and the right hand), while responses to large numbers were faster with the right key (left hand). However, it's worth noting that Wood et al. (2006) reported a failure to replicate this finding. Building on the study by Dehaene and colleagues (1993), de la Vega et al. (2013) conducted a follow-up study with the primary objective of disentangling this phenomenon and examining whether the BSH was related to an individual's hand or extracorporeal space.

In de la Vega et al. study (2013), participants (all right-handed individuals) engaged in a valence judgment task. They pressed keys on a keyboard using their crossed dominant and non-dominant hands within the same session. Specifically, they used their dominant right hand to press the left key ("Q") for positive images and their non-dominant left hand to press the right key ("9") for negative images. Despite the incongruent information conveyed by the hands and the spatial area of key pressing, the study found that the association between hand and valence took precedence over the association between side and valence.

Participants were still faster with their right-dominant hand for positive stimuli and their left non-dominant hand for negative stimuli in the condition where hands and side conveyed incongruent information.

Nevertheless, as previously mentioned, our Experiment I contrasts with the findings of de la Vega et al. (2013). In Experiment I, we identified both a space-valence association (related to the extracorporeal space) and a hand-compatibility effect (related to an individual's hand, i.e., the intracorporeal space), namely hand-valence associations. Consequently, we can assert that all these effects are manifestations of the same phenomenon (the BSH), without one necessarily prevailing over the other.

In Experiment I, in contrast to the study by de la Vega et al. (2013), participants responded with one hand at a time in two separate sessions, enabling us to differentiate between hand and side effects. This alone might suggest that there is no prevalence of one effect over another, even when hand and side convey different information. However, we hypothesize that tasking participants with one hand (right or left) at a time in two separate sessions could yield different results than having the right-dominant and left non-dominant hands alternately respond in the same session.

At this juncture, it is crucial to conduct a more in-depth examination of the intra- and extracorporeal associations of the BSH and verify, in a follow-up study (Experiment III), whether the association between hand and valence would override the one between side and valence by placing participants in the same condition as de la Vega et al. (2013) study.

To achieve this, participants should respond with their hands crossed employing the set-up of de la Vega et al. (2013) study. Specifically requiring participants to cross their hands in the incongruent condition already adopted in Experiment I will allow us to differentiate between hand and space. In this case participants will swipe right for negative images with their left hand and will swipe left for positive images with their right hand. This approach will ensure that hands and space conveyed contrasting information, aligning with the design of de la Vega et al. (2013) study.

In consideration of these factors, Experiment III aims to address the following research questions:

1. Would alternating the dominant and non-dominant hand within the same experimental session lead to different outcomes compared to Experiment I?
2. If affirmative, would this provoke a primacy of the intracorporeal manifestation (hand-valence associations) of the BSH over the extracorporeal one (space-valence associations), aligning with the results reported by de la Vega et al. (2013)?

Two possible outcomes could be anticipated:

1. A potential primacy of hand-valence over space-valence associations, aligning with the findings of de la Vega et al. (2013). If this holds true, our hypothesis is that placing participants in both conditions (congruent: swipe right for positive, swipe left for negative; incongruent: swipe left for positive, swipe right for negative) to swipe with their right dominant hand for positive images and with their left non-dominant hand for negative images could potentially neutralize the difference between conditions (space-valence associations). This is because hand-valence associations would likely dominate over space-valence associations.
2. Alternatively, no clear precedence of one effect over the other, mirroring the results of Experiment I. In this case, we would expect both space valence associations (i.e., faster responses in the congruent condition; swipe right for positive, swipe left for negative compared with the incongruent condition; swipe left for positive, swipe right for negative) and hand-valence associations (e.g., faster responses for negative stimuli with the non-dominant left hand and/or faster response for positive stimuli with the dominant right hand). This is the outcome we anticipate since it aligns with the outcomes of Experiment I.

While theoretically possible, the predominance of space-valence associations over the hand-valence effect is not expected, given the absence of similar results in both our study (Experiment I and Experiment II) and the existing literature.

To test these hypotheses, we conducted a follow-up study to Experiment I with right-handed individuals. The stimuli, materials, and procedure mirrored those of Experiment I, with the only difference being that participants were instructed to perform the swipe gesture using both their right-dominant and left non-dominant hand, alternated within the same session.

In the congruent condition (swipe right for positive images, swipe left for negative images), the hands (right and left) were positioned parallel to each other, conveying information congruent with the spatial arrangement. In contrast, in the incongruent condition (swipe right for negative, swipe left for positive), the hands were crossed (i.e., the right hand in the left space, the left hand in the right space), carrying contrasting information with respect to the spatial arrangement.

It's noteworthy that, in this setup, regardless of hand position and conditions, participants' dominant right hand consistently interacted with positive images (swiping them to the right space in the congruent condition and to the left space in the incongruent condition). Conversely, their non-dominant left hand consistently interacted with negative images (swiping them to the left in the congruent condition and to the right space in the incongruent condition).

6.2 Method

Participants

A total of N=30 right-handed participants, (21 females, M_{age} = 26.53, SD_{age} = 3,64) from the University of Milan-Bicocca voluntarily took part in Experiment III. Based on existing literature using a similar procedure (de la Vega et al., 2013) and on an a priori power analysis using the G*Power software (Faul et al., 2007), a sample size of N=30 participants was estimated to have 80% probability to detect a significant interaction (α=.05) with a medium effect size (r=.25) in a mixed model, following Cohen's guidelines (Cohen, 1977). All participants read and signed a consent form prior to data collection in accordance with the Declaration of Helsinki (World Medical Association, 2013). Handedness was tested with the Edinburgh Inventory (Oldfield, 1971), in Italian translation. Ethical approval for the study was received by the Committee for Research Evaluation of the University of Milan-Bicocca (Protocol number: RM.2022-544).

Design

The study employed a 2 x 2 within-subjects design, where the experimental Condition (Congruent, parallel hands vs Incongruent, crossed hands), and Valence (positive vs negative) were the factors. Response time (RT) served as our dependent variable.

Apparatus and stimuli

The materials and stimuli were the same as those employed in Experiment I.

6.3 Procedure

The procedure remained unchanged from that of Experiment I, with the sole difference being that participants were instructed to execute the swipe movement using both hands within the same session. In the congruent condition, (swipe right for positive, swipe left for negative) the hands were positioned in parallel, while in the incongruent condition (swipe right for negative, swipe left for positive), the hands were crossed.

6.4 Statistical analysis

Data were analyzed with a linear mixed effects model (LMM) with the software Jamovi version 2.3 (*The Jamovi Project*, 2023). All statistical tests were conducted on a two-tailed .05 level of significance. To select an appropriate random component, we started setting all plausible effects as random. A model with the intercept and valence included as random coefficients was the one that converged. Thus, the final model had as random coefficients the intercept and valence across all the main effects and their interaction instead were included as fixed factors. Only RT corresponding to correct answers were preserved in the statistical analysis, leading to the exclusion of 3.21% of data. Among correct responses, RT greater or less than 2 SDs of the subject average were excluded from further analyses (0,84%).

6.5 Results

A significant main effect of Condition was found, F (1,1521.4)= 8.99, p = .003 showing higher RTs in the Incongruent condition (i.e., crossed hands) compared with the Congruent condition (i.e., parallel hands) (Figure 6). Interestingly, a main effect of Valence was found F(1, 29.8)= 16.81, p < .001 indicating a faster response to negative images with the non-dominant left hand regardless of Condition (Figure 7). The interaction effect between Valence and Condition yielded a non-significant result, F (1, 1536.4) = 0.10, p = .74).

Effects plots

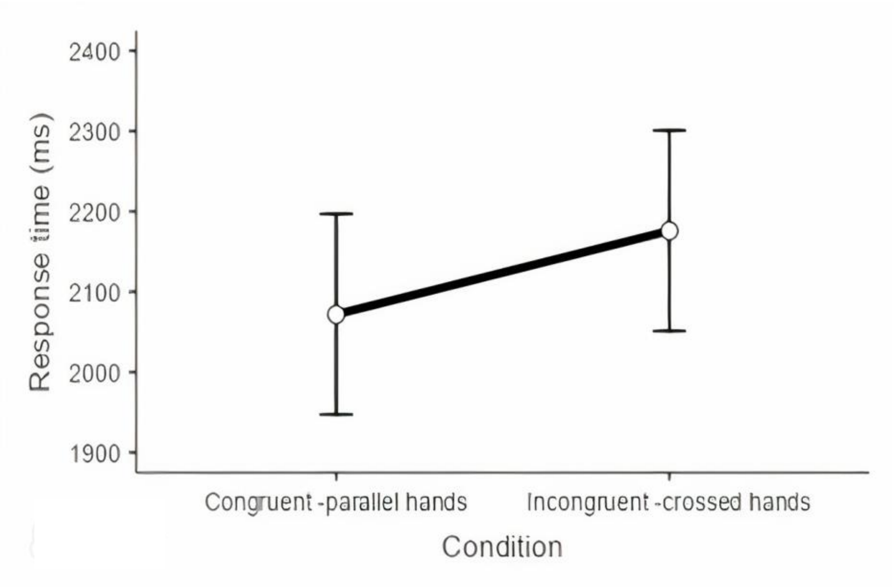

Figure 6. RT as a function of Condition with higher RT for the Incongruent condition compared with the Incongruent (p = .003). Error bars indicates Standard Error (SE).

Figure 7. RT as a function of Valence with lower RT for negative images (p <.001). Error bars indicates Standard Error (SE).

6.6 Discussion

The purpose of Experiment III was to build upon the findings of Experiment I. In Experiment I, we observed that body-specific associations, explored in a response time paradigm involving the swipe gesture, could manifest simultaneously as both intra- and extra-corporeal phenomena. This was evidenced by the presence of both space-valence associations and hand-compatibility effects (i.e., hand-valence association). It's worth noting that in Experiment I, right-handed participants were tasked with one hand at a time.

Our objective was to verify whether administering the same task as in Experiment I but requiring participants to engage in the same session using both dominant and non-dominant hands would result in a stronger connection between hand and valence, as opposed to the connection between space and valence, aligning with the results of de la Vega et al. (2013). In the study conducted by de la Vega et al. (2013), a valence judgment task was administered, where hand and side conveyed contrasting information (i.e., participants pressed “Q” with their right hand for positive words and “9” with their left hand for negative words).

In Experiment III, following the set-up of de la Vega et al. (2013) study, the incongruent condition (e.g., swipe right for negative images and swipe left for positive images), allowed us to distinguish between hand and space by requiring participants to hold their hands crossed. In Experiment III the hands were crossed, as we have already done with one hand at a time in Experiment I. In this setup, with hands crossed, participants encountered incongruent information between hands and space (e.g., swipe left with the right hand for positive images; swipe right with the left hand for negative images).

Conversely, in the congruent condition (e.g., swiping right for positive images and left for negative images), participants' hands were parallel to each other. This setup ensured congruent information conveyed by both hands and sides (e.g., swiping right for positive images with the right hand, swiping left for negative images with the left hand) while maintaining the involvement of both hands simultaneously in the same session. The experiment's logic rested on enabling the distinction between two alternative expected results:

1) the hand-valence association (i.e., hand compatibility effect) would override the space-valence associations (e.g., faster responses in the congruent condition compared with the incongruent), aligning with de la Vega et al. (2013) results. In other words, placing participants in both conditions (congruent vs incongruent) to respond with their dominant right hand for positive images and with their non-dominant left hand for negative images could nullify the differences between conditions, since hand-valence associations would dominate over space-valence associations. Thus, we might expect a hand-compatibility effect irrespective of experimental conditions.
2) No precedence of one effect over the other. This second possibility is the one we hypothesized, mirroring the results of Experiment I. In this scenario, we could anticipate the presence of both space-valence associations (indicated by faster responses in the congruent condition—swipe right for positive, swipe left for negative—compared to the incongruent

condition—swipe left for positive, swipe right for negative) and hand-valence associations (such as faster responses for negative stimuli with the non-dominant left hand/faster responses for positive stimuli with the dominant right hand).

Results were consistent with our hypothesis, since findings of Experiment III are basically overlapping with those of Experiment I. Space-valence associations emerged, since right-handed participants show a preference for the congruent condition (swipe right for positive; swipe left for negative) as compared to the incongruent (swipe left for positive; swipe right for negative). In addition, a main effect of valence was found, indicating that right-handed participants exhibited lower RT when swiping negative images compared to positive ones, regardless of the conditions (congruent-parallel hands vs incongruent-crossed hands).

It's worth noting that, in both conditions, participants interacted with negative images exclusively using their non-dominant left hand, whether the hands were crossed or parallel. Quite surprisingly, we could assert that the non-dominant left hand is strongly associated with negative valence. Conversely, for the right dominant hand, this association might be weakened by the presentation of conflicting information, such as swiping to the left for positive stimuli. This result supports the hand-valence association identified in Experiment I, where the interaction between hand and valence showed the fastest response times for negative stimuli when using the non-dominant left hand.

Considering these results, it can be posited that the BSH effect manifests as both an intra-corporeal and extra-corporeal phenomenon, without a clear dominance of one over the other. In this scenario, this study serves as an initial demonstration of the concurrent existence of intra- and extra-corporeal manifestations of BSH through a swipe gesture.

Nevertheless, it is crucial to note the inherent limitations when comparing our study to the work of de la Vega et al. (2013), who employed linguistic stimuli and a keyboard. The use of a mobile touchscreen interface with a swipe gesture in our study precludes a direct comparison with that specific research. Nonetheless, these results may introduce a new dimension for research, presenting challenges for further exploration in this domain.

Conclusion

In conclusion, our findings provide additional evidence supporting the idea that both the intra-corporeal and extra-corporeal manifestations of BSH can be considered as multimodal expressions. In summary, these results highlight the connection between valence and spatial orientation, originating from an individual's body—specifically, in how easily individuals use their dominant versus non-dominant hand when judging positive or negative stimuli. Depending on the nature of the task (e.g., verbal, pressing a key, swiping gesture, etc.), this correlation may manifest more prominently as either space-valence associations or hand-valence associations.

7. Experiment IV - The impact of spatial placement on valence judgments of images: a comparative analysis between right-handed and left-handed individuals

7.1 Introduction

In Experiment I and Experiment II, we investigated the BSH using a lateralized (hand) swipe gesture task for valence judgments. Our results collectively provide support for the BSH, although some desensitization to body specificity effects occurred when both left-handed and right-handed individuals used their dominant hand.

Right-handers showed faster responses when their responses aligned with their space-valence associations (swipe right for positive, swipe left for negative) rather than incongruently (swipe right for negative, swipe left for positive), regardless of the hand involved in the swipe gesture. Additionally, regardless of the condition, right-handed individuals also tended to respond faster with their non-dominant hand when swiping for negative images compared with positive ones (i.e., hand compatibility effect). This effect was not observed when swiping for positive images with the dominant right hand, suggesting a form of implicit adaptability for this hand.

Similarly, left-handed individuals exhibited implicit adaptability when responding with their dominant left hand in both experimental condition (congruent vs incongruent). However, when using their non-dominant right hand, they showed faster responses in the congruent condition (swipe right for negative, swipe left for positive) compared with the incongruent condition.

Furthermore, considering the valence reinforcement effect observed in left-handed participants, we hypothesize that accommodation in left-handed individuals is evident only when making implicit judgments of valence.

Collectively, Experiment I and Experiment II highlight the importance of swipe direction (swipe right vs swipe left) and its alignment with the space-valence associations of individuals, considering that the swipe gesture in many digital applications carries inherent meaning (swipe right for positive, swipe left for negative). In other words, with Experiment I and Experiment II, we demonstrated the influence of motor instructions (and their motor feedback) on emotional assessment. Our dependent variables encompassed response time and valence evaluation, representing implicit and explicit measures, respectively.

While prior research extensively examined response time within the framework of BSH (de la Vega et al., 2012, 2013; Kong et al., 2012; Milhau et al., 2015), limited attention has been given to the influence of the spatial placement of stimuli on valence evaluation without motor feedback (e.g., without hands or feet movements). In this vein, a few studies (Everhart et al., 1996; Natale et al., 1983) have examined the effect of the spatial placement of stimuli on valence judgments, exclusively focusing on facial expressions as stimuli. Specifically, in a valence judgment task (Natale et al., 1983), individuals with right-handed dominance judged all expressions except happiness as more negative when presented in the left visual field. This effect was smaller for left-handers and was absent in left-handers who use the non-inverted writing posture.

However, in a study by Everhart et al. (1996), a different pattern was observed: while right-handed participants consistently perceived neutral faces regardless of the visual field, left-handed individuals evaluated neutral faces as more positive (happy) when presented in the left visual field and more negative (angry) when presented in the right visual field.

Furthermore, Casasanto's (2009) investigations primarily focused on the spatial positioning of stimuli, either through drawing or vocal instructions, such as in the “Bob goes to the zoo task,” or through binary choices tasks. Similarly, in Experiment 5 (Casasanto, 2009) participants were instructed to attribute positive or negative qualities to items (alien creatures) positioned on the right or left side (Experiment 5).

Considering the limited evidence concerning the impact of spatial stimuli on explicit valence evaluation, we assert that it is crucial to deeply investigate this aspect in absence of motor responses. Specifically, we think it is worth investigating whether body-specific associations might be evident in a valence judgment task involving images that are neutral valence- laden and that will be placed alternately at the center, right, and left of a screen. Those images should be presented to both right-handed and left-handed participants.

It is important to underscore that when we refer to body-specific association, we refer to the valence reinforcement effect that have been found over time in studies involving lateralized hands movements (for example, see Cervera Torres et al., 2020), as well as in Experiment II addressed in the preceding paragraphs. The rationale for investigating this phenomenon considering exclusively the different (center vs right vs left) placement of stimuli is diverse.

Firstly, it is necessary to consider that if, in the "Bob goes to the zoo" task (Casasanto, 2009), positive animals were associated with the right side by right-handed individuals and with the left side by left-handed individuals, then hypothetically, presenting images on the right, left, and center of the screen could also potentially modify valence judgments within right-handers and left-handers respectively, as well as between right-handers and left-handers

Secondly, excluding those few studies (Natale et al., 1983; Everhart et al., 1996) that used exclusively facial expressions as stimuli, as mentioned earlier, the valence reinforcement effect has been investigated more when associated with hand movements, typically lateralized (Cervera Torres et al., 2020; Milhau et al., 2013).

For example, in the study conducted by Milhau et al. (2013), during a valence judgment task, right-handed participants who performed smooth rightward arm movements using an evaluative scale aligned with their space-valence association (where positivity was linked to the right and negativity to the left) tended to offer more positive assessments for neutral words. Conversely, when executing non-fluent leftward movements with an incongruent scale, participants displayed a tendency toward negative evaluations. Therefore, it can be assumed that studies exclusively examining the exposure of stimuli to the right and left are indeed scarce (Everhart et al., 1996; Natale et al., 1983) and those few have focused on a single type of stimuli, namely, facial expressions.

Considering these factors, the research questions of Experiment IV, therefore, are as follows:

(1) Does observing the same stimuli, which are slightly leaning towards neutrality and placed alternately at the center, right, and left of a screen, influence participants' valence evaluations in alignment with their own space-valence associations?

(2) If so, do variations in valence evaluations exhibit distinctions between right-handed and left-handed individuals consistent with their own space-valence associations?

Expected results are as follows.

a) **Research question 1**

   According to the BSH, we hypothesize that for both right-handed and left-handed participants, there will be an effect of image location. Specifically, we expect higher (i.e. more positive) evaluations towards images positioned on the space of the screen aligned with the space towards the dominant hand of participants (generally associated with positive concepts). On the contrary, we expect lower evaluations (i.e. negative) for images positioned on the side of the screen congruent with the non-dominant side of the participants, which is generally associated with negative concepts.

   However, alternatively, considering some habituation effects we observed in left-handed and right-handed individuals in Experiment I and II, it is possible that the hypothesized trajectories may not be entirely linear. If this is the case, then no significant differences will be found in the valence evaluation of images positioned on the right, center, or left of a screen.

b) **Research question 2**

We hypothesize that images placed on the left side of a screen will be judged more positively by left-handed participants compared to right-handed participants; conversely, we also hypothesize that images placed on the right side will be judged as more positive by right-handed participants and less positive by left-handed participants.

To test these hypotheses, we conducted a valence judgment task, where participants were asked to evaluate the valence of stimuli positioned in the center, right, and left of a screen in two different experimental sessions.

7.2 Method

Participants

A total of N=30 (20 females, M_{age} = 27.72, SD_{age} = 3,62) participants of which N=15 right-handed and N=15 left-handed participants, from the University of Milan-Bicocca as volunteers took part in Experiment III. All participants had normal or corrected to normal vision and were naive to the purpose of the experiment. Based on existing literature using a similar procedure (Everhart et al., 1996) and on an a priori power analysis using the G*Power software (Faul et al., 2007), a sample size of N=30 participants was estimated to have 80% probability to detect a significant interaction (α=.05) with a medium effect size (r=.25) in a mixed model, following Cohen's guidelines (Cohen, 1977). All participants read and signed a consent form prior to data collection in accordance with the Declaration of Helsinki (World Medical Association, 2013). Handedness was tested with the Edinburgh Inventory (Oldfield, 1971), in Italian translation. Ethical approval for the study was received by the Committee for Research Evaluation of the University of Milan-Bicocca (Protocol number: RM.2022-544).

Design

The study utilized a 3 x 2 mixed-design, incorporating both within-subjects and between-subjects factors. The factors included image location (center vs right vs left) as a within-subject factor and handedness (right-handed vs left-handed) as a between-subject factor, with Valence Evaluation (VE) serving as the dependent variable.

Apparatus and Stimuli

The experimental setup involved using a Galaxy Chromebook Go laptop with a 14.0-inch display with a resolution of 1366x768 pixels for presenting stimuli. To run the experiment the same native Android mobile app developed by the BiCApP (Bicocca Center for Applied Psychology) for both Experiment I and Experiment II was used. This app, built according to the "React Native" framework (Zammetti, 2018), was integrated with Qualtrics, (https://www.qualtrics.com/). It automatically recorded all user-sessions data in a non-interactive Qualtrics survey, with information represented through embedded fields.

In terms of stimuli, we selected 36 images (500 × 400 pixels) from the Open Affective Standardized Image Set (OASIS, Kurdi et al., 2017), an open-access online stimulus set containing 900 color images depicting a broad spectrum of themes. The OASIS database including humans, animals, objects, and scenes, along with normative ratings on two affective dimensions—*valence* (i.e., the degree of positive or negative affective response that the image evokes) and *arousal* (i.e., the intensity of the affective response that the image evokes) both measured on 7-point Likert scale (1=very negative, 2=moderately negative, 3=somewhat negative, 4=neutral, 5=somewhat positive, 6=moderately positive, and 7=very positive). For the arousal dimension, the term "arousal" was presented above the rating scale, and the scale points were labeled as "very low," "moderately low," "somewhat low," "neither low nor high," "somewhat high," "moderately high," and "very high".

We selected images covering four main themes: scenes (N=12), objects (N=11), and animals (N=13), by choosing images with neutral valence (i.e., corresponding to a rating of 4, indicating "neutral") and low arousal (ranging from a minimum of 1 to a maximum of 2, indicating "very low" or "moderately low"). This choice mirrors that made by Milhau et al. (2013), who used neutral words for their experiment.

7.3 Procedure

The experiment comprised two experimental sessions separated by a 3-week washout period. During the first session, participants undertook a valence evaluation task featuring a set of 36 images presented in a randomized order. The images were exclusively shown at the center of the screen. This first session served to obtain a baseline measure of valence evaluation (VE) for the images. In the second session, each image from the set was randomly presented once on the right side of the screen and once on the left side. Before starting the experiment, participants were informed that a second session would be administered after three weeks.

Participants were comfortably seated at a desk. The experimental setup involved using a laptop (Galaxy Chromebook Go) positioned approximately 70 centimeters away, strategically placed at the center of the desk, and aligned with the body's midline. After a concise introduction to the study and completion of informed consent procedures, including the provision of personal information such as age, gender, and educational level, the task commenced.

A brief training session, featuring two images, preceded each main session. In the first session, the task involved presenting a single image at the center of the screen for a duration of 4 seconds. Subsequently, on a new screen, participants were instructed to judge whether the previously seen image was positive or negative by clicking on a vertically oriented 9-point Likert scale made of small squares numbered from 1 to 9, ranging from 1=very negative to 9=very positive. After their response, a countdown timer from 3 to 1, lasting 750 milliseconds, preceded the presentation of each new image for valence evaluation.

The task (repeated) in the second session closely mirrored that of the first session, with the primary difference being the location of the images on the screen. In the second session, images appeared alternately on the right and left sides of the screen. To ensure variety and prevent order effects, we prevented images from appearing consecutively first on one side and then on the other side, with at least ten different images interspersed between repetitions. Each experimental session lasted approximately 10 minutes. As a result, each participant viewed and evaluated a total of 108 images (36 images for each of the three positions: 36 images in the first session and 72 in the second session)

7.4 Statistical analysis

Data were analyzed with a linear mixed effects model (LMM) with the software Jamovi version 2.3 (*The Jamovi Project*, 2023). All statistical tests were conducted on a two-tailed .05 level of significance. To select an appropriate random component, we started setting all plausible effects as random. The model that converged included only the intercept as random coefficients. Therefore, the final model featured a random intercept across participants as random factors, with handedness (right-handed vs left-handed), locations (center vs right vs left), and their interaction as fixed factors. To calculate p values estimates for the fixed effects, it was used a Type III Satterthwaite approximation (e.g., Carr et al., 2016).

7.5 Results

The main effect of Handedness was not statistically significant, $F(1, 28.1) = 0.41$, $p = .52$, indicating that Handedness alone did not significantly influence VE. Similarly, the main effect of Location was not significant $F(2, 3019.9) = 1.59$, $p = .20$, suggesting that Location alone did not have a significant impact.

However, there was a tendency toward significance (“close to significant” effect) in the interaction between Handedness and Location $F(2, 3025.8) = 2.39$, $p = .09$, indicating that the combined influence of Handedness and Location on VE may be worth further investigated.

We then performed a singular test (Fixed effects parameter estimates) on this interaction. The test (Table 3) revealed a statistically significant effect for the interaction between Left-handers and Right-handers with Location (b= 0.31, SE = 0.14, $p = .02$) at the “Left vs Center” images location. Specifically, left-handers, compared to right-handed participants, tended to assign higher VE to images located on the Left side versus the Center side of the screen (Table 4, Figure 8).

Fixed Effects Parameter Estimates

Names	Effect	Estimate	SE	95% Confidence Interval Lower	95% Confidence Interval Upper	df	t	p
(Intercept)	(Intercept)	5.6370	0.1207	5.4004	5.8736	55.2	46.698	< .001
Handedness1	Left-Handers - Right-Handers	0.0988	0.1526	-0.2004	0.3979	28.1	0.647	0.523
Location1	Right - Center	-0.0993	0.0727	-0.2419	0.0432	3026.8	-1.366	0.172
Location2	Left - Center	-0.1224	0.0728	-0.2650	0.0202	3027.0	-1.682	0.093
Handedness1 ✻ Location1	Left-Handers - Right-Handers ✻ Right - Center	0.1570	0.1443	-0.1258	0.4399	3042.2	1.088	0.277
Handedness1 ✻ Location2	Left-Handers - Right-Handers ✻ Left - Center	0.3157	0.1444	0.0327	0.5988	3042.5	2.186	0.029

Table 4

Effects Plots

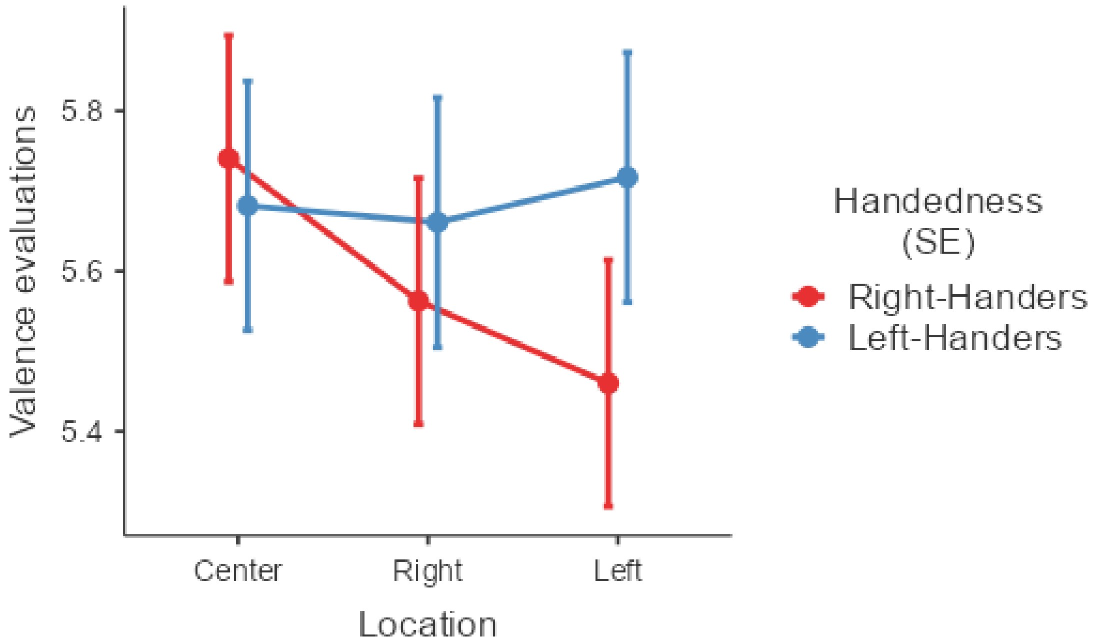

Figure 8. Plot show a significant interaction between Handedness and Location (Left vs Center) on Valence Evaluations (p=.02). Red line indicates Right-handed, while the blue line indicates Left-Handed. Error bars depict Standard Errors (SE).

Simple effects analysis

For a more detailed examination of the effects of Location on VE, we conducted a simple effects analysis of Location with Handedness (right-handers vs left-handers) as the moderator. The omnibus test revealed that only for right-handed participants there was a significant effect of Location on VE, $F(2,3037) = 3.72$, $p = .02$, indicating that VE varied across different locations (Table 5).

Specifically, in right-handed individuals, VE was lower in the Left position compared to the Center position ($p = .007$) (Table 6). Notably, right-handed participants also tended to evaluate images slightly more positively when they were in the Right position compared to the Centre position. However, this difference was close to significance ($p = .08$).

Conversely, in left-handed participants, there was no significant effect of Location on VE, $F(2,3037) = 0.16$, $p = .85$, suggesting that the relationship between Location and VE did not differ significantly among diverse locations (Table 5).

Simple effects of Location: Omnibus Tests

Moderator levels				
Handedness	**F**	**Num df**	**Den df**	**p**
Right-Handers	3.722	2.00	3037	0.024
Left-Handers	0.159	2.00	3037	0.853

Table 5

Simple effects of Location: Parameter estimates

Moderator levels				**95% Confidence Interval**				
Handedness	**contrast**	**Estimate**	**SE**	**Lower**	**Upper**	**df**	**t**	**p**
Right-Handers	Right - Center	-0.1779	0.104	-0.382	0.0258	3037	-1.712	0.087
	Left - Center	-0.2802	0.104	-0.484	-0.0766	3037	-2.698	0.007
Left-Handers	Right - Center	-0.0208	0.101	-0.219	0.1772	3037	-0.206	0.837
	Left - Center	0.0355	0.101	-0.163	0.2338	3037	0.351	0.726

Table 6

7.6 Discussion

The purpose of Experiment IV was to contribute to the investigation of the BSH (Casasanto, 2009) by examining valence evaluations of neutral images across different spatial locations (center vs right vs left) *within* both right-handed and left-handed individuals, as well as *between* right-handed and left-handed individuals. The task involved evaluating the valence of 36 images on a 9-point vertically oriented Likert scale. In the first session, the stimuli were presented at the center of the screen. In the second session, the same stimuli were alternately presented on both sides, once on the right and once on the left.

Building on the BSH proposed by Casasanto (2009), our expectation was that both right-handed and left-handed participants would exhibit higher (more positive) evaluations for images positioned on the side of the screen aligned with their dominant hand (associated with positivity). Conversely, we anticipated more negative evaluations (lower) for images positioned on the side of the screen congruent with their non-dominant hand (associated with negativity).

Alternatively, considering the habituation effect observed in both left-handed and right-handed individuals during Experiments I and II, we entertained the possibility that no significant differences would be found in the valence evaluation of images positioned on the right, center, or left side of the screen.

The obtained results partially align with our predictions. Although the omnibus test did not produce significant results for the (image) Location factor, significance was shown for certain levels of the location factor (fixed affects parameter estimates). Specifically, as further clarified by the simple effects analysis, valence evaluations were lower in the Left location compared to the Centre location for those with right-handed dominance.

However, for left-handed individuals, as also confirmed by the simple effects analysis, we did not achieve statistical significance. This implies that the effect of location on valence ratings does not appear to differ significantly for those with left-handed dominance.

Furthermore, a significant interaction between Handedness and Location was also shown. Right-handed tended to assign lower valence ratings (i.e. more negative) to images located in the left part of the screen compared with left-handed.

Taken together, these results partially support the BSH (Casasanto, 2009): right-handed behave in accordance with the BSH, while left-handed individuals did not show such a trend.

Specifically, right-handed and left-handed exhibited distinct patterns. Right-handed showed a linear decreasing trend in scores from the Center to the Left location, starting with high ratings for images located at the Center and gradually decreasing from Right to Left, showing a significant effect only in the "Center vs Left" comparison. In contrast, left-handed individuals, showed no difference in their evaluations.

From this, we can deduce that compared to the baseline position "Center," the body specificity effect is stronger (reaching statistical significance) with images placed on the left side of the screen rather than on the right. This leads us to speculate that the left side (non-dominant) of right-handed individuals is more sensitive to the position of the images in the space. These results converge with those of Experiment I, where the hand-valence association was absent when the dominant right hand was used but very evident when the non-dominant left hand was used.

In contrast, left-handed display a markedly different, almost flat trajectory. Consistent with Experiment II, they once again demonstrate greater adaptability (i.e., they seem more accustomed to evaluations not consistent with their space-valence associations), with no significant differences observed between center, right, and left image locations.

Conclusion

In conclusion, our findings emphasize the intricate interplay of handedness and location in shaping participants' valence perceptions. The effects uncovered in this study highlight the importance of considering these factors in future research on valence assessments, particularly in scenarios where spatial location plays a prominent role. These results provide valuable insights into the cognitive processes underlying valence assessments and contribute to a deeper understanding of how individual characteristics may influence subjective evaluations.

8. General discussion

Recent research on both adults and children has shown that our bodies and our interactions with the physical world play a crucial role in shaping our thoughts and perceptions (Barsalou, 2009; Riskind & Gotay, 1982). In other words, cognitive processes are influenced by our physical experiences and bodily interactions, as proposed by the BSH (Casasanto, 2009). More precisely, the BSH proposes that individuals tend to associate “positive” concepts with the space around their dominant hand, and “negative” concepts with the space around their non dominant hand.

Casasanto (2009) suggested that these space-valence associations are influenced by motor fluency since actions performed with the dominant hand are perceived as easier and more fluent, leading to positive affect (Beilock & Holt, 2007; Carey et al., 1996).

Studies supporting the BSH have shown space-valence associations in various contexts, such as response time paradigms (de la Vega et al., 2012; Kong et al., 2013; Milhau et al., 2013, 2015), real-life simulations like job interviews and product selection (Casasanto, 2009, Experiment 5), and politicians' gestures during speeches (Casasanto & Jasmin, 2010). These associations are not fixed, as evidenced by studies manipulating motor fluency, revealing changes in space-valence associations (Casasanto & Chrysikou, 2011).

In a study conducted by de la Vega et al. (2012), in a lexical decision response time procedure, right-handed participants, when specifically attending to the valence and side mapping of valence-laden words, exhibited quicker judgments of positive words using their dominant hand on the right side of the keyboard. Conversely, negative words were assessed more rapidly when participants employed their non-dominant hand to press a key on the left side of the keyboard. Interestingly, this hand compatibility effect (i.e., hand -valence association), where the dominant hand reacted faster to positive stimuli and the non-dominant hand reacted faster to negative stimuli, was replicated in left-handed participants, displaying an opposite pattern to that of right-handers.

The robustness of the hand compatibility effect was further confirmed in a subsequent study by de la Vega et al. (2013). This follow-up investigation allowed for a clear distinction between the hand effect itself and the spatial locations of keys on the keyboard—factors that were confounded in the preceding study (de la Vega et al., 2012).

Notably, de la Vega et al. (2013) were the only one directly tested the hand compatibility effect (i.e., hand-valence associations) against the spatial side effect (i.e., space-valence associations). The results of this follow-up study provided clear evidence that, in situations of conflicting information, the hand indeed overrides the side in shaping the body-specific associations. These results highlighted the intracorporeal origin of the BSH (i.e., hand-valence associations over the extra-corporeal (i.e., space-valence associations).

In addition, another phenomenon that has not been fully investigated is the valence reinforcement effect, which is still limited to a few studies where motor feedback by hands was always present (Cervera Torres et al., 2020; Milhau et al., 2013). It is worth noticing that certain linkages between spatial orientation and affective valence have been explored albeit restricted to the examination of facial expressions (Everhart et al., 1996; Natale et al., 1983).

This thesis aimed to extend previous evidence on the BSH in a swiping paradigm, particularly by verifying whether body specific associations including space-valence associations, hand-valence associations, and valence reinforcement effects would manifest in a valence judgment task conducted trough a swipe gesture on the touchscreen of a tablet.

Our primary objective was to examining body-specific associations in settings that mimic real-world scenarios and verifying whether body specific associations extend to commonplace "digital" gestures, like the swipe gesture. This gesture has become ubiquitous in our interactions with digital touchscreen interfaces, especially on smaller to medium-sized devices, and has developed specific connotations over time. Commonly, the swiping right gesture is linked with positive valence, while swiping left is often associated with negative valence.

Thus, directly exploring these swipe gestures was instrumental in addressing persistent questions that had arisen from previous studies, particularly the observation that the effects (space-valence/hand-valence associations) discovered seemed to be short-term. Consequently, a pertinent question arose regarding the resilience of the BSH to cultural influences. This led to contemplation on whether relatively "new" gestures, such as swiping, have indeed transformed our perception and interaction with the extern world.

Hence, in the Experiment I and Experiment II both right-handed and left-handed participants were instructed to swipe right for positive images and left for negative ones, and vice versa (i.e., swipe right for negative and left for positive).

Specifically, in both Experiment I and Experiment II, participants engaged in a valence judgment task involving images with positive and negative connotations. They provided responses through a right/left swipe gesture, using one hand at a time, specifically the dominant and non-dominant hand. Additionally, participants were tasked with evaluating the valence levels of each image using a vertically oriented one-dimensional 9-point Likert scale. The direction of the positive and negative swipe responses was manipulated in congruent and incongruent conditions based on participants' natural space-valence associations.

In the congruent condition, it aligned with the space-valence associations of either right-handers or left-handers (right-handers' associations: swipe right for positive and swipe left for negative; left-handers' associations: swipe right for negative and swipe left for positive). In the incongruent condition, the response direction dissociated with participants' space-valence associations (i.e., for right-handers: swipe right for negative and swipe left for positive; for left-handers: swipe right for positive and swipe left for negative).

Aligned with the BSH (Casasanto, 2009), we anticipated divergent patterns for right-handed and left-handed participants. Specifically, we expected right-handed individuals to respond faster when swiping right for positive images and swiping left for negative images (congruent condition), compared to the opposite pattern (swiping right for negative, swiping left for positive, incongruent condition). Conversely, we predicted the reverse pattern for left-handed participants.

Additionally, we considered an alternative hypothesis, considering the possibility that space-valence associations could be influenced by the prevalent use of mobile applications (such as dating apps). Indeed, in the digital realm, swiping right is commonly associated with a positive or forward action, while swiping left is linked to a negative or backward action.

In essence, these connotations align with the space-valence associations of right-handed individuals. With this in mind, we speculated that left-handers might display a pattern of associations like those of right-handers, associating the right side with positive valence and the left side with negative valence.

Considering this speculation, we initially tested the swipe gesture on right-handed participants (Experiment I). Subsequently, we replicated the task with left-handed participants (Experiment II), who served as a crucial component in balancing the outcomes of this study.

Results indicated that right-handed participants were faster in swiping images congruently to their usual space-valence associations with both their dominant and non-dominant hands, while left-handed individuals exhibited this effect only with the non-dominant right hand.

This suggests that for the emergence of space-valence association, the responding hand is crucial for left-handed, indicating greater adaptability in left-handers' interactions with the environment. As a result, we might posit that left-handers inherently associate negative connotations with conditions that are congruent with their established associations only when using their non-dominant right hand. However, when using their dominant left hand, this association is mitigated by their familiarity with experiencing incongruities due to navigating in a right-handed-friendly environment.

However, it is important to emphasize that in left-handers individuals this adaptability occurs only at the implicit level. In fact, surprisingly, left-handed participants, unlike to their right-handed counterparts, showed significant differences in valence evaluations levels, (i.e., valence reinforcement effects) with more positive and negative evaluation in the congruent condition compared to the incongruent one independently by the hands involved.

Additionally, another noteworthy effect observed in right-handed participants (Experiment I), but not in left-handed ones (Experiment II), was the hand compatibility effect (i.e., hand-valence associations), addressing the intracorporeal origin of the BSH. Specifically, right-handed individuals showed faster responses to negative images with their left hand compared to their right hand. Strikingly, this type of hand compatibility effect was not observed in left-handed participants.

At this purpose, Experiment III, conducted as a follow-up to Experiment I, delves into the debate of extra vs intracorporeal shifts of the BSH. The specific aim was to examine and consider whether body specificity associations should be categorized as originating within the body (intracorporeal) or extending beyond the body (extracorporeal). The study's findings suggest that the BSH can manifest as both an intracorporeal and extracorporeal effect simultaneously, even when there is incongruent information conveyed by hands and side. This nuanced perspective challenges the dichotomous view presented by de la Vega et al. (2013).

Finally, Experiment IV investigated the impact of the spatial location of stimuli (neutral images) on valence evaluation in both right-handed and left-handed individuals. Results show that the locations (right vs center vs left) of stimuli (i.e. neutral images) on a screen could influence the valence evaluation of right-handed individuals. Importantly, this effect showed statistical significance only in the comparison between the center vs left locations, where we observed a valence reinforcement effect. On the contrary, for left-handed individuals, there were no statistically significant differences in valence evaluations across various stimuli.

Interestingly, we found an interaction effect between handedness and location. Specifically, right-handers and left-handed individuals significantly differed in the evaluation of neutral images located on the left side of the screen. Right-handers tended to give lower evaluations (more negative) when compared with left-handers.

Altogether, the four experimental studies presented in this thesis contribute new insights to the current literature on EC, emphasizing the complexity of the interaction between handedness, space-valence associations, hand-valence associations, and valence reinforcement effects when declined in a motor response paradigm.

Furthermore, our experimental paradigm underscores that interaction with a mobile touchscreen, specifically through the swipe gesture, strengthens body-specific associations more robustly than tasks relying solely on cognitive associations tasks (e.g., pressing a right key for positive and a left key for negative). In the latter type of task, even if the required response is motor based (such as pressing a key), the association is not inherently tied to the task, whereas interacting with a touchscreen concurrently links the response with the action. Touchscreen interaction thus enhances the connection between the body and space, a relationship inherently linked to physical action. Importantly, these studies offer insights grounded in real-world scenarios, providing a valuable perspective within ecological settings.

Firstly, the exploration of space-valence associations, traditionally confined to experimental tasks such as preference tasks (e.g., Casasanto, 2009), speech analysis (Casasanto & Jasmin, 2010), and response time paradigms (de la Vega et al., 2012, 2013; Milhau et al., 2013, 2015), has been expanded to include ecological environments such as mobile devices (i.e., tablets), specifically investigating the swipe gesture (Experiment I).

Secondly, the swipe gesture, as mentioned earlier, plays a crucial role in an authentic digital language used in daily life, with its distinct set of meanings. Consequently, in our perspective, it signifies the exemplary gesture for exploring BSH in an ecologically manner.

From this standpoint, Experiment I is a pioneer in employing a mobile touchscreen to specifically investigate the BSH. Our study represents the initial instance of utilizing a mobile touchscreen device that limits movement across the body's midline, isolating hand and finger movements from the influence of the rest of the body. This addresses a confounding factor present in the Cervera Torres et al. (2020) study where a large touchscreen (23 inch) crossing the body's midline was used to display stimuli.

Experiment III serves as an initial illustration of the simultaneous presence of intra- and extra-corporeal manifestations of BSH facilitated by a swipe gesture. Notably these findings marked the endpoint of previous investigations into BSH, examining it as both an intracorporeal (de la Vega et al., 2013) and an extra-corporeal phenomenon (Casasanto, 2009).

Finally, Experiment IV contributes novel insights as it marks the initial demonstration of a valence reinforcement effect in right-handed individuals contingent on the location of images (center vs left) without involving any lateral movements of hands, such as motor feedback. Additionally, Experiment IV represents the first evidence of a disparity in valence evaluation between right-handed and left-handed individuals based on image location.

In summary, this thesis suggests that in ecological environments the BSH is influenced by a universally understood digital language—specifically, the swipe gesture, which carries inherent meanings. This adaptability is observed in various ways among individuals who are right-handed and left-handed.

Indeed, through a comparison of findings between these two groups, Experiment II emphasizes that left-handed participants exclusively display space-valence associations with their non-dominant right hand, in contrast to their right-handed counterparts who exhibit space-valence associations with both hands. This provides evidence for the extra-corporeal origin of BSH.

On the other hand, right-handed individuals (Experiment I) demonstrate hand-valence associations with their non-dominant left hand, particularly in response to negative stimuli, supporting the intracorporeal origin of BSH. Interestingly, their response times are even faster than with their dominant right hand. However, no hand-valence associations were observed in left-handed individuals.

Notably, intriguing results emerged for both right-handed and left-handed individuals, particularly when considering the non-dominant hand, which, theoretically, is less influenced by continuous interactions with digital devices. Specifically, hand-valence associations between the right-dominant hand and positive stimuli were not observed in right-handed individuals. Similarly, left-handed individuals did not exhibit space-valence associations when using their dominant left hand, indicating a form of 'desensitization' to body-specific associations. We attribute this 'desensitization' to the habitual nature of swiping right or left, especially with the dominant hand. This observation is unsurprising, given that, in real life, left-handed individuals have had to adapt to a world primarily designed for right-handed individuals.

Experiment III delves into the intra/extra-corporeal origin of the BSH, uncovering a coexistence of both space-valence and hand-valence associations. These results challenge the conventional division between hand-valence and space-valence associations in the scientific literature. Our data suggest that examining both associations together provides a more comprehensive understanding of the phenomenon.

Furthermore, the adaptability observed in Experiment I and Experiment II is also reflected in the behavior of left-handers in Experiment IV, where they did not show any significant variations in valence evaluation towards neutral images. In contrast, right-handed individuals exhibited a statistically significant difference when comparing the center vs left location. However, comparing the results of Experiment IV and Experiment II left-handers show a different pattern of responses. While Experiment II revealed a valence reinforcement effect in the congruent condition compared to the incongruent, no such difference emerges in this experiment. We attribute this to the fact that, for left-handers, motor feedback evidently constitutes a substantial part for the emergence of body specific effects.

Clearly, we acknowledge that Experiment I and II are based on a different experimental paradigm as compared to Experiment IV. Nonetheless, these initial data pave the way for new speculations and further studies to explore the effect of image locations on valence.

In conclusion, the four experimental studies presented in this thesis contribute significant advancements to the existing literature on EC. They intricately explore the relationship between handedness, space-valence associations, hand valence associations and valence reinforcement effects, offering valuable insights within real-world ecological settings.

Undoubtedly, the experiments in this thesis present certain limitations. Firstly, despite undergoing a manipulation check, the assessment of stimuli utilized in Experiments I, II and III did not include an evaluation in terms of arousal, which was instead present in Experiment IV. This is a noteworthy constraint, as images capable of inducing high arousal may have been appraised more swiftly, potentially introducing confounding factors into the results.

Secondly, another limitation arises from the inability to fully compare Experiment I and II with Experiment IV, given the use of different stimuli in the two experiments. While these studies offer intriguing insights and open avenues for further exploration, we acknowledge the limitation imposed by the non-comparability of stimuli.

Moreover, an alternative theory has been proposed to explain compatibility effects between binary dimensions such as stimulus-response mappings. Proctor and Cho (2006) introduced the polarity correspondence principle, suggesting that: "For a variety of binary classification tasks, people code the stimulus alternatives and the response alternatives as + polarity and – polarity, and response selection is faster when the polarities correspond than when they do not" (Proctor & Cho, 2006, p. 418). The coding of + or − depends on the salience of the alternative, with the most salient modalities being plus polarities and the less salient being minus polarities. For instance, positive valence (right or up) is typically a plus polarity, while negative valence (left or down) is a minus polarity (Lakens, 2012; Proctor & Cho, 2006).

In order to consider Experiment I and Experiment II of this thesis in the light of polarities, the most fluent condition (i.e., congruent condition) can be regarded as the most salient and would, therefore, be coded as +. Indeed, right-handed participants were faster in the congruent condition, were the stimulus alternatives and the response alternatives correspond, than could be coded as +.

Furthermore, in this sense, also ipsilateral actions (i.e., executed on the same side as the effector acting: right hand to the right, left hand to the left) can be considered more fluent than contralateral ones and are, therefore, coded + (Lakens, 2012; Proctor & Cho, 2006). Indeed, in Experiment I, we observed that right-handed participants were faster in swiping with the left hand for negative images.

Nevertheless, these results are consistent with the embodied cognition theory according to which sensorimotor processes, crucial for our interactions with the environment, enable organisms to process sensory information and respond through coordinated motor actions. The embodied mind perspective posits that these processes not only support action but also exert a substantial influence on cognition (Wilson, 2002).

This work, therefore, substantiates the idea that emotional evaluation stems from sensorimotor engagements with the (digital) environment. It indicates that the processing of valence-laden objects can potentially reactivate previous sensorimotor and affective responses associated with them, a phenomenon known as valence-compatibility effects (Scerrati et al., 2023).

In summary, the thesis suggests that within ecological environments, the BSH demonstrates susceptibility to the pervasive digital language, particularly through the swipe gesture, with embedded connotations. This permeability manifests in diverse ways among individuals, discernibly distinguishing between right-handers and left-handers.

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