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Whether and How Handedness Affects Individuals' Cognitive Performance?

– A Literature Review

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Abstract: This literature review article aimed to compile research published in recent years regarding the relationship between bodily habits, specifically handedness, and cognitive performance in memory, attention, and information processing. The article contains three chapters, discussing each aspect separately with a collection of studies and evaluations. The article is able to combine results from studies and form a model graph specialized for studies' summaries. Through the synthesis of investigations, handedness seemed to have some relationship with cognition. To be more precise, ICH individuals (those people with mixed hands) have the capacity to create a connection between brain hemispheres, which enhances their performance in memory tests and allows them to better integrate divergent information. In addition, people tend to focus more on their dominant hands; this can affect a person's attention to things happening around them. Lastly, right-handed people performed better in generic cognition tests, and cross-activation of brain lateralization has been demonstrated.

Keywords: Cognitive performance, Handedness, Memory, Attention, Processing

1. Introduction

When it comes to the world of science, the human brain is one of the most fascinating things to explore. Back then, Galen, a Roman physician who lived in the first century BC, proposed that the four ventricles of the brain, which are fluid-filled cavities, are where sophisticated thought, personality, and bodily functions are controlled. This was one of the earliest arguments in favour of the idea that our memories, personalities, and thought processes all reside in the brain [1]. The phrase "cognitive psychology" was initially coined by psychologist Ulric Neisser, who described it as the study of the mechanisms underlying information perception, transformation, storage, and retrieval [2]. During the years, cognitive psychology gained prominence strikingly, and cognitive performance

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is a vital area that comprises noted topics but is not restricted to attention, memory, and problem solving, which psychologists have been studying in this field [3]. According to the introduction to cognitive performance published in 2021 [4], people can account for memory, attention, and the ability to process as typical aspects of a human's cognitive performance. To elaborate, memory can be explained as "Any state or process that results from the sequential stages of encoding, storage, and retrieval" [5]. On the other hand, attention can be directed at four fundamental procedures: working memory, top-down sensitivity control, competitive selection, and automatic bottom-up filtering for prominent stimuli [6]. Finally, the ability to process includes but is not limited to the processing of auditory or visual input, reasoning, and logic or arithmetic-related skills [4].

On the other side, regarding people's bodily habits, there is a ubiquitous categorization that says humans can be divided into three groups: right-handed, left-handed, and mixed-handed, and among these groups, only about 10 percent are left-handed [7]. Based on those, the present study would like to discover how bodily differences, specifically handedness, impact individuals' cognitive performance. Many studies on this topic have been published over the years, but there are only a few review articles that performed a meta-analysis, or a literal summary based on them.

This review article aims to investigate whether there is a relationship between cognitive performance and handedness and what the results of this relationship are. To be more precise, the main research question for this review article is: Whether Left-Handed and Right-Handed individuals have different levels of cognitive performance (confined to three subjects: memory, attention, and the individual's processing of information), and how are they different? Hence, the present research will compare handedness with these three subjects in chapters, respectively. The studies collected for this current essay comprised empirical and review articles. More explicitly, these empirical articles incorporated different methodologies of research, including both objective (for instance, physiological measures and the discovery of brain lateralization) and subjective outcomes. With various data types and the summary of the most current research, this review article is able to provide new insights into the field of bodily habits and cognitive performance.

2. Handedness and Memory

Although it is not known whether human behavior is controlling the brain, or the brain is controlling human behavior. But in people's cognition, the relationship between a person's behavior and his brain is very close. And when people think about the brain, "memory" is the first thing that most people will think of. The ability to remember is one of the representatives of the ability of the brain.

Handedness, or the preference for using one hand over the other, has been the subject of cognitive research, particularly in relation to memory functions. The complex relationship between handedness and memory can be divided into two primary categories: working memory and retrospective memory.

2.1. Working Memory and Handedness

Working memory is an essential cognitive system that is frequently compared to the brain's "mental workspace." It is responsible for the transient storage and manipulation of information and plays a crucial role in a variety of cognitive tasks, including reading and comprehension, problem-solving, and decision-making.

Numerous studies have investigated the correlation between handedness and working memory. The apparent advantage of right-handed individuals in working memory tasks is one of the most intriguing findings from Alipour et al. [8]. This advantage is not just a matter of hand preference but is profoundly rooted in the structure of the brain. The left hemisphere, which controls the right hand in the vast majority of right-handed people, is frequently associated with linguistic and logical tasks.

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This specialization for verbal processing, a crucial aspect of working memory, may account for the superior performance of right-handed people [9].

However, handedness is not a strictly binary phenomenon. Beyond the conventional categories of right- and left-handedness, there exists a group of individuals with inconsistent hand choice (ICH). Rather than displaying a clear preference for one hand, these individuals tend to use both hands for various duties. The third citation introduces an enticing plot twist to the story. It indicates that the degree of handedness, not just its directionality, can affect cognitive functions such as episodic memory [10]. This nuanced perspective suggests that ICH individuals may benefit from increased interhemispheric communication due to their tendency to engage both hemispheres more actively. This enhanced connectivity could provide them with an advantage in tasks requiring the integration of disparate information, a characteristic of working memory.

In essence, although right-handed individuals may flourish in working memory tasks due to the verbal prowess of their left hemisphere, the cognitive landscape is more complex. Due to their unique brain dynamics, ICH individuals may be better equipped for tasks that require a harmonious interaction between the two hemispheres. Then, what about the retrospective memory? Besides its association with working memory, what does handedness have to do with the retrospective memory?

2.2. Retrospective Memory and Handedness

As opposed to the real-time processing of working memory, retrospective memory serves as our personal time machine, allowing us to recall past experiences, knowledge, and skills. This type of memory is crucial to our identity because it helps us make sense of the present and plan for the future.

The intricate interplay between handedness and retrospective memory has piqued the interest of scientists. This relationship is illuminated by the third source, which reveals that individuals with inconsistent hand choice (ICH) reported fewer complaints about their retrospective memory [10]. Such findings challenge conventional wisdom, which predominantly considers the handedness's directionality (right versus left). Instead, it focuses on the degree or consistency of hand preference as a more significant factor in episodic memory performance [10].

Hemispheric Encoding and Retrieval Asymmetry (HERA) provides a compelling framework for investigating neurocognitive mechanisms in greater depth. The left hemisphere of the brain is responsible for encoding memories, while the right hemisphere is responsible for retrieval [10], according to this model. This hemispheric division of labor indicates that the two halves of the brain collaborate in the memory process. Individuals with ICH have a tendency for increased interhemispheric activation, which may result in a more seamless integration between encoding and retrieval processes, giving them a possible advantage in memory tasks.

Another intriguing aspect of this discussion is the significance of grasp strength. Frequently viewed as a physical indicator correlated with handedness, grip strength has been linked to reduced complaints of retrospective memory loss [10]. However, this association is not simple. Grip strength may be a surrogate for a variety of underlying factors, including general health, metabolic function, and even regular participation in physical activities. For example, a stronger grip may indicate improved overall health, which may in turn promote optimal brain function and memory performance.

The relationship between handedness, grasping strength, and retrospective memory is complex and multidimensional. Other factors, such as general health and brain connectivity, play crucial roles in determining our ability to recall the past, whereas hand preferences may be advantageous for certain memory tasks. So, are there any specific experiments that can intuitively reflect the difference between left-handed, right-handed and mixed handed? And how is handedness determined?

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2.3. A Meticulous Summary of a Study

Handedness was either determined by the Edinburgh Handedness Inventory or the Briggs and Nebes handedness questionnaire. In the Edinburgh Handedness Inventory, developed by Richard Oldfield, is a questionnaire that asks the participant to report which side that they would use for everyday tasks such as writing, using a pair of scissors, or opening a box; however, they could also perform the task for direct observation [11]. They are given a point for how many tasks they prefer each hand for before calculating their Laterality Quotient, the percent of tasks they prefer using their right hand for. The Briggs and Nebes handedness questionnaire is a very similar questionnaire; however, it is entirely self-reported [12]. For both questionnaires, there is a similar number of tasks and there are five different categories in order to scale the degree of handedness.

It is acknowledged that handedness can influence memory because of our brain asymmetry. While we are aware that certain parts of our brain are more heavily involved in memory retention, there are also different types of memory. Most of the research involving handedness and memory focuses on various types of long-term memory rather than short term memory. Within long-term memory, some common focuses include episodic memory, implicit and explicit memory.

After previous results showed that mixed handers often had an advantage in episodic memory, Lyle aimed to verify if this result applied to a practical setting as well [13]. Eyewitness memory is a critical exercise in episodic memory. While there have been many cases where eyewitness testimonies proved crucial to an investigation, there have also been cases where it allowed the wrong person to be convicted. This put into doubt the reliability of eyewitness testimonies; however, in this research, Lyle explores whether it is possible to see if inconsistent handers are more reliable than consistent handers [13].

In the first experiment, Lyle used cued recall to test episodic memory while in the second experiment, free recall was used. In both experiments, it was found that inconsistent handers were able to recall more information than a consistent hander [13]. This is consistent with previous findings. This study is a step in simulating real world circumstances for applications of memory research, however, there remains more steps that could be taken. This research was only able to use a slideshow as the evidence for the participants to remember while a video would more closely resemble a real-world situation.

2.4. Summary

Handedness, a seemingly basic trait, has profound effects on cognitive functions, especially memory. The intricate relationship between handedness and both working and retrospective memory demonstrates the complexity and plasticity of the brain. Right-handed people appear to have a natural advantage in tasks requiring working memory, but the situation is more complex when contemplating retrospective memory. Here, the degree or consistency of hand preference among ICH individuals emerges as a potentially more influential variable.

In addition, the significance of grasp strength cannot be overstated. In addition to being a merely physical characteristic, grip strength may serve as an indicator of broader neurological and physiological health, thereby influencing memory performance. As we continue to uncover the intricacies of the brain, it is evident that handedness, grip strength, and memory interact in a complex web of interconnected factors. Future research endeavors in this field have the potential to enhance our comprehension, leading to interventions that can enhance the memory performance of various populations.

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3. Attention

Using memory alone as a reference is not enough to explain whether there is a relationship between handedness and cognitive performance, so attention is also an important research direction. Trying to imagine that when two identical balls are on a person's left and right, does that person's dominant hand determine which ball he will focus on first?

Attention can be affected by handedness due to social, biological, and psychological reasons. It affects attention in many different ways, but also a span of many different types of attention. The two major types of attention it has heavily influenced are visual attention, and attention-span-based-mental-illnesses. The way that people with different hand preferences differ in terms of visual sensitivity is what part of their body triggers an increase in sensitivity and what doesn't. This difference is caused by the dominant use of one particular side of the body over the other, causing the brain to be familiarized more with one side. In other words, if a right hander's right hand was in his field of vision, his visual sensitivity would be increased, same as if a left hander had their left hand in their field of vision. This is demonstrated in an experiment conducted by Nathalie Von Bigot on perch and space. The experiment included subjects placing their hands into four different positions: both hands present, no hands present, left hand present, and right hand present. In each of those positions they complete the task of distinguishing the vague contents of a screen displaying either the target "x", or the distractor "+". The experiment showed that when a person's dominant hand was put beside the monitor, their distinguishing capabilities were increased and therefore performed better. The reason why humans have this feature is most likely because "visual processing in perch and space is closely tied to potential forthcoming actions" [14]. Humans maximized their movement potential by subconsciously focusing their visual attention more to their dominant hand's movements, which is where most of the action would take place.

This leads to the conclusion that handedness does indeed affect the human mind, specifically the way they would perceive in correlation with their dominant hand. However, not only does handedness affect people as individuals, but it also affects us as a group. Since most people across all the world's societies are naturally right-handed, people have developed an unintentional increased awareness towards other people's right side – their own left. This increases perception towards the actions or potential actions of the other's right hand in the future, regardless of the dominant hand of the observer. An example of such increased sensitivity toward other's hands have affected us is in sports: in paddle-based sports, people are so attuned and familiarized with the actions of an opponent's right side (left side in the viewer's perspective) that when facing a left-handed opponent, struggle with predicating the movement and therefore pathway of the incoming stroke [15]. Hence why masters of Ping Pong claim that being left-handed is such an advantage in the novice to intermediate years (although the unfamiliarity also affects left-handed athletes). Such advantages are not limited only to paddle sports, combat sports are also affected: fencers also have a difficult time predicting a left-handed opponent's left-hand movements, since they have also competed predominantly against right-handed opponents [16]. The fact that most people are right-handed would be the reason for people's sensitivity towards others' right side. Thus, once again leading to the conclusion that visual attention is affected by handedness, and by extension, the way people think and perceive.

Many early studies of attention and handedness tended to ascribe the control of visuospatial attention to hand dominance and hemisphere dominance. Bisiacchi et al. supported the idea of a right-hemisphere involvement in attention [16]. However, recent studies presented by Rinaldi et al. proposed that the control of visuospatial attention is mediated by a dynamic interplay among biological (i.e., right hemisphere dominance), biochemical (i.e., hand dominance), and cultural (i.e., reading habits) factors. And such control factors of visuospatial attention result in advantages and biases in performance in visuospatial attention [17]. Bisiacchi et al. discovered that left-handed

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fencers showed significantly faster reaction times with their left hand in the unattended situation [14]. Similarly, the study outlined by Wühr and Ansorge investigated the impact of the dominant hand on performance in two paper-and-pencil tests of visual selective attention (d2-R; FAIR-2), in which a group of left-handed students (n = 86) and a group of right-handed students (n = 90) completed both the test d2-R and the test FAIR-2 with their dominant (writing) hand [18]. It turned out that left-handed participants outperformed right-handers in both tests. Bisiacchi et al. attributed the advantages to the involvement of the right-hemisphere in attention [16]. They also suggest that right-hemisphere lesions can affect attentional performance, which further reinforced their statement.

Alongside with the attentional performance, studies also addressed the concept of attentional bias and laterality effects. Studies by Foundas et al. found both right- and left-handed adults showed increased lateral biases when attention was directed to either ear, supporting the attentional hypothesis (i.e., each hemisphere primarily directs attention to the contralateral space, and speech stimuli activate the left hemisphere, leading to a right-ear bias) [19]. And especially, right-handed individuals exhibited a greater shift in bias when directing attention leftward. Likewise, Colman et al. suggest that biased visuospatial attention enhances object identity discrimination near hands and that these effects are particularly enhanced for right-handers, as right-handed individuals showed increased response time effects when cues were near the graspable area compared to the non-graspable area of their dominant hand, while these effects were not observed for their non-dominant hands and not present for left-handed individuals [20]. In summary, the impact of handedness on attention is a multifaceted interplay of biological, biochemical, and cultural factors. While early research associated visuospatial attention with hemisphere and hand dominance, recent studies reveal a more intricate relationship. Left-handed individuals demonstrate unique attentional advantages and biases, shedding light on the influence of handedness in shaping attention processes. Additionally, attentional bias and laterality effects further underscore the intricate connection between handedness and attention. This body of work highlights the need for a holistic understanding of how cognitive, neural, and physical elements converge to shape attention among individuals with varying handedness preferences.

4. Handedness and Processing

Thinking about the three elements of cognitive performance mentioned at the beginning, this article has explained the relationship between handedness and memory and attention. So, this chapter is going to focus on how handedness affects humans processing abilities. Including auditory, visual, and problem-solving skills. While processing is a large portion within cognitive performance, it is also a crucial factor in our daily lives; there are plenty of stimuli around, and our brain processes them when they transfer through it and build our perceptions. This present study would like to explore whether different bodily habits like hand preference would affect the way people dispose of stimuli, build perceptions, and impact other related abilities, as well as how left-handed and right-handed individuals differ in these portions. We hypothesized: 1) Left-handed individuals have better performances regarding creative and visual elements. 2) Right-handed individuals are better in arithmetic problem solving and related cognition tasks.

4.1. Auditory and Visual Processing

Auditory and visual inputs have emerged as key methods for investigating the relationship between handedness and processing. In this section, we will delve into the connection between handedness and processing, informed by several prior studies.

Grey et al. explored the relationship between handedness and morphosyntactic processing by analyzing the ERP patterns of left-handed participants (LH), right-handed participants without

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familial sinistrality (RH FS-), and right-handed participants with familial sinistrality (RH FS+) [21]. Their findings suggest that both LH and RH FS+ groups exhibit a heightened reliance on lexical/semantic mechanisms compared to the RH FS- group. These results offer a fresh perspective for distinguishing between the RH FS+ and RH FS- groups and underscore the importance of accounting for this variability in subsequent study. However, the study's ecological validity might be limited as all 60 participants were monolingual native English speakers from a single local university.

In a subsequent study employing fMRI methods, the influence of handedness on language processing was further explored, revealing that the degree of handedness (DH) modulates sentence comprehension [22]. This supported previous findings suggesting that DH affects the strategy employed during sentence comprehension [23]. Nonetheless, the inclusion of only 40 right-handed participants from a single university may limit the study's ecological validity and generalizability.

The samples in the following three studies cater to specific populations, thus possibly affecting the broad applicability of their findings. For instance, research focusing on sign language comprehension and production postulates that the sign comprehension is driven by both comprehension and production systems, and the complexity determines the dominance. The result shows that left-handed individuals responded more quickly to two-handed signs when they were made by left-handed signers than when made by those who were right-handed [24]. A separate study by Smit and Sadakata posited that pianists' capacity to adapt to unfamiliar spatial and motor configurations may be influenced by their handedness. The result shows that left-handed pianists demonstrate increased speed and precision when playing melodies using reversed finger patterns compared with right-handers [25]. Finally, a study exploring the interplay between handedness and cognition in individuals with Multiple Sclerosis (PwMS) found that dextral PwMS generally outperformed non-dextral PwMS in combined assessments of memory and IQ. This highlights the significant influence of handedness and hints at a heightened vulnerability of the left brain to the pathological processes associated with Multiple Sclerosis [26].

4.2. Problem Solving and the Arithmetic Aspect

As the previous section discussed how visual and auditory processing can be affected by handedness, this section continues to pay closer attention to how handedness affects processing. To be specific, how does handedness influence people's problem-solving skills and their Arithmetic aspects?

Empirical articles in this field use different methodologies to investigate a certain idea. One experimental study regarding how handedness influences individuals through five cognition tests revealed that right-handed participants have better performances on timed cognition tests. This might be interpreted as meaning they have faster processing speeds and better problem-solving skills [27]. However, this study only included participants from one university; therefore, the ecological validity of this study might be reduced. Another experimental study that focused on functional lateralization of arithmetic processing, a more physiological aspect, elucidated those left-handed participants showed stronger functional right-lateralization in the IPS (bilateral intraparietal sulcus) task [28]. This result gives other researchers a crucial insight, which suggests that activation like bilateral IPS patterns may be shaped by functional lateralization, which is the reason why left-handed and right-handed people are different. This provides another step in investigating how this lateralization impacts other cognitive tasks.

Nonetheless, a later study conducted in 2023 by Lagares et al. suggests that their study on arithmetic problem solving found no significant differences between left-handed and right-handed individuals; however, those individuals with one hand preference performed with a faster response time than mixed-handed individuals. This study included a total of 15,000 participants, which increased its generalizability and validity [29]. In the past few years, there have been a number of studies that have revealed differences between left-handed and right-handed people. A case on the

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investigation of parity judgement focused on how people of different handedness respond to numbers. To be precise, to judge numbers (odd or even) with either the left or right hand The result revealed that the MARC (markedness of response codes) effect, which is "the markedness of the words even vs. odd and right vs. left", depended on the degree of handedness [30]. Those with more dominant left-handed habits showed a reverse MARC effect, whereas those with less dominant left-handed habits exhibited a regular MARC effect. The reverse version of the MARC effect is a comparable faster response to even numbers with the left hand and odd numbers with the right hand, the opposite of the regular MARC effect [30].

Further on arithmetic and number processing, results have shown that when it comes to collision detection, which is a test specialised in investigating people's space-time processing and their arithmetic evaluation, The study concluded that left-handed people have higher accuracy [31]. The results of studies like this led to a convincing explanation of how different sensorimotor experiences appeared to be different between right- and left-handed people. Handedness can, therefore be seen as an intermediate between task and people's performance. Since sensorimotor experiences can result from different patterns of brain lateralization, disparate habits of handedness contribute to the different channels that a person's perception goes through, giving rise to different cognitive performance. In addition, a study has shown that handedness can form an association with mathematical performances; however, more studies need to be conducted in order to understand the whole mechanism. In particular, right-handed individuals are more likely to experience a deficit in spatial ability, which affects their mathematical abilities [32]. Regarding creatively related problem-solving tasks, a study discovered that left-handed participants exhibit higher digressive schizotypal tendencies, which indicates that they tend to have better performance on divergent problem-solving tasks [33]. The results of this study conformed with previous studies results, as mentioned. However, there are also some contradictions, as some previous studies had shown that left-handedness was not a factor that predicted divergent thinking skills, yet this study might be outmoded [34].

4.3. Summary

In conclusion, left-handed and right-handed individuals performed differently in different factors. Methodologies within this aspect of research include both physiological measurements like fMRI and behavioral experiments that involved participants performing certain tasks; thus, a quite comprehensive form of the data was collected. Meanwhile, there are still mechanisms that need further investigation in order to get a deeper understanding of how handedness diverges in functional lateralization and performance on cognition tests. Overall, our summary generally supports our hypotheses. Left-handed individuals perform better on divergent problem-solving and some processing tasks that required people's comprehension skills. On the other hand, right-handed individuals perform better in generic cognition tests. Nevertheless, left-handed participants showed stronger functional right-lateralization regarding arithmetic processing, which is contrary to our previous belief that right-handed people are more likely to perform better in arithmetic aspects. There were also studies that believed there was no significant differentiation between left- and right-handed people. It is likely to be concluded that there are numerous theories on how handedness leads to variability in cognitive performance. Further studies are required to explore the underlying mechanisms and retest those theories.

5. An Integrated Summary

Figure 1 summarized studies in this review and figure 2 delineates the relationship between handedness and processing. In this model, the two ovals represent latent or unobserved variables, which are "Handedness" and "Cognitive Performance". While the rectangles denote the manifest or

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observed variables related to various cognitive abilities. The potential effects are represented by directed arrows. There are three main pathways in this model. The first pathway is from handedness to observed variables, which indicates that the handedness of an individual is hypothesized to influence specific cognitive abilities. It highlights the direct effects of handedness on cognition covered in the review, such as auditory and visual processing and problem-solving skills. The second pathway is from observed variables to cognitive performance, which suggests that each cognitive ability is hypothesized to contribute to the overall cognitive performance. The third pathway is from handedness to cognitive performance, which denotes that handedness might have a direct influence on overall cognitive performance due to the intricate relationships and potential direct or indirect effects between handedness, individual cognitive abilities, and overall cognitive performance. While the proposed processing model offers a structured visualization of potential relationships, it is not without limitations. First and foremost, the model necessitates empirical testing for validation. Moreover, some studies discussed in the review possess limitations. Future research could focus on collecting data to test and validate the proposed relationships within the model.

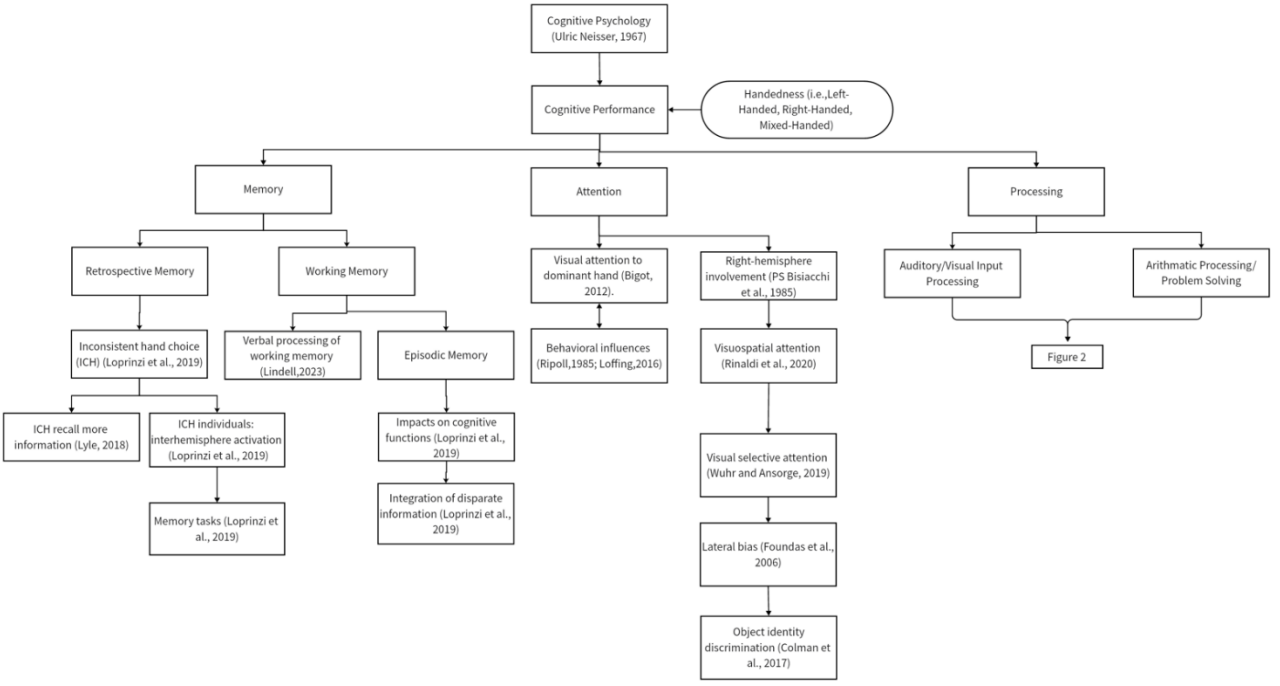

Figure 1: A Literature Summary Graph

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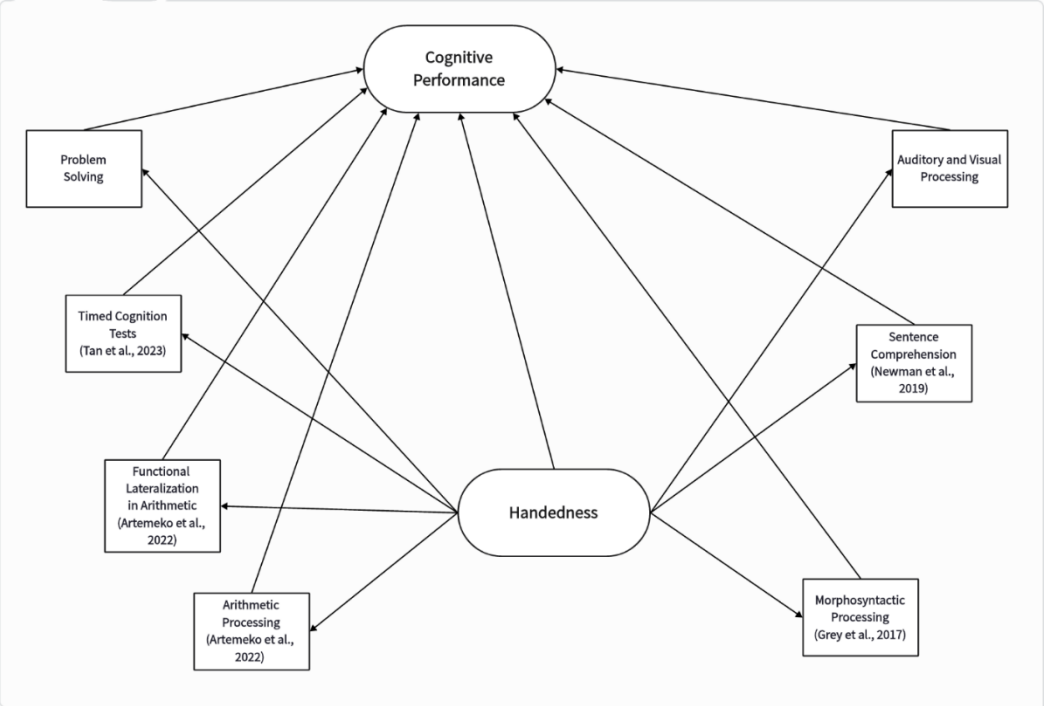

Figure 2: Processing and Cognition Graph

6. Conclusion

This literature review discussed how handedness can impact different aspects of people's cognition. This article started with addressing how handedness affects people's memories. Dividing this topic of memory into subdivisions of working memory and retrospective memory, this article found that right-handed individuals had an advantage in terms of working memory with an addendum that ICH individuals may have an advantage in other working memory tasks that required more interhemispheric interactions. Meanwhile, when studying retrospective memory, it was more beneficial to have ICH. Another notable addition to the discussion of handedness and memory was that of grip strength, a common measure of handedness. Grip strength, while possibly an indication of general healthiness, is also correlated to better retrospective memory and therefore remains a current area of research.

The next aspect of cognition in this literature review was attention. There are several hypotheses for how handedness impacts the direction of one's attention such as the hypothesis that right handers focus most of their attention on their right side as that is the space where they are likely going to perform any actions in. Similarly, in sports such as ping pong and fencing, people generally have an increased awareness of an opponent's right hand due to the expectation that they would be a right hander. While there is a large focus on visual attention, these biases can also be found elsewhere such as in hearing.

Lastly, this literature review has discussed handedness and cognitive processing such as auditory, visual, and problem solving skills. Some studies that has been found concluded that while right handers performed better in generic cognition tests, left handers performed better in divergent problem solving taste as well as arithmetic processing. However, other studies concluded that there was no significant difference between left and right handers. These contradictory findings show potential for further testing of these hypotheses and provide room for further research.

Throughout the various research that has been explored, the present study observed that within recent years, there was an increased focus on the degree of handedness. However, many of these

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studies had a limited pool of participants and some of them found contradictory results. Further research into these areas could result in having a clearer idea of the mechanisms behind the differences between the degrees of handedness as well as a better understanding of how this impacts people.

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