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Review

Behavioral Research in Construction Engineering Management: A Review from a Neuropsychological Perspective

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Abstract: In construction engineering, there are many interactive and decision-making behaviors which could affect the progress and final performance. Based on the people-oriented concept, managing construction engineering should not ignore the understanding of individual behavior, and neuropsychology provides a refined microscopic perspective. This paper employed a bibliometric analysis of 1254 studies from the Web of Science related to behavioral research in construction engineering management using VOSviewer and summarized the neuropsychological mechanisms and research methods of behavior by systematic review. This paper found that: (1) Neuropsychological mechanisms of behavior include basic mechanisms about the brain and function and range from sensory to decision processes. Core factors are the functional ingredients. (2) Behavior research in construction engineering management is turning to neuropsychological experiments. Understanding the complex correlation mechanisms are the research trends in recent years. (3) Construction engineering management studies provide the means and methods to improve the validity and efficiency of management in the construction industry. The results confirm the impact of sensory perception on behavior and managerial performance. (4) The research trend in this field in the future is multidisciplinary. In total, this paper provides a potential effective reference for improving the performance of construction engineering management, developing sustainable construction production and consumption, and building a people-oriented livable city.

Keywords: construction engineering; management; behavior; neuropsychology; bibliometric analysis

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1. Introduction

People have been thinking about themselves and understanding their behaviors since ancient times, and this is reflected in ancient Western and Eastern culture. However, limited by science and developing technology, it has mainly manifested in the level of philosophical thinking. Modern science has shown that all human behaviors are inseparable from neural mechanisms. It has become common knowledge that the brain controls human behavior. However, understanding how it works requires thinking about the nature of the mind, the representation of emotions, and the responsibility for behavior [1]. The development of neuroscience and modern technology provided more possibilities for the theoretical exploration and practical application of neuropsychology.

In the relationship between the brain and behavior, the early positions were mainly localizationism and equipotentialism [2]. Localism believes there is a connection between certain areas of the brain and specific behaviors, for example, movement and perception. Meanwhile, other research argues behavior has more of a quantitative role than the type and location of brain tissue. Modern neuroscience rejects the extremes of these two opinions but draws inspiration from both and merges them. Recognizing the crucial role of the brain in behavior, the research of medicine and psychology began to consider using behavioral interventions on brain damage diagnosis, evaluation, and repair [3].

Neuropsychology in behavioral research refers to applying neuroscience theories, techniques, and methods to better understand the process of individual behavioral decision-making and results [4]. Similar behaviors within and among individuals may result from different underlying neuropsychological mechanisms that are imperceptible to many traditional research methods [5]. There is a view that objective neuropsychological data are less susceptible to subjective bias and are therefore more reliable than self-reports [6]. However, interpreting objective data needs to be undertaken with rigorous neuropsychological knowledge, and plenty of reported information can often help. In this sense, the self-report of the subjects can have a better auxiliary effect. Therefore, more researchers preferred the mixed method of combining self-report with experimental measurement.

In construction engineering management (CEM), many interactive and decision-making behaviors exist in actual works; for example, communication among workers, interaction between workers and equipment, spatial relationships between workers and the environment, and behavioral decisions that occur in the construction. All these critical or daily behaviors could affect the progress and the final performance of the construction project. As proof, safety and risk control in the construction progress is of great concern to both academia and industry. In past research and practices of CEM, managers paid more attention to structure, material, and the use of technical tools, and sometimes as well as the construction process control and standardization of workers' operating behavior. Instead, they focused little on the effects of human neurological function and psychological feedback on behavior. Recently, researchers have begun to explore the influence of neuropsychological factors on personnel behavior, especially the factors related to construction engineering, including physical fatigue [7], mental fatigue [8], attention failure [9], and others. However, there is still a lack of neuropsychological considerations in the preliminary design, operation, supervision, and acceptance of construction engineering management.

This review implemented people-oriented development and humanistic care and tries to offer a systemic outline of human behavior research in construction engineering management from the perspective of neuropsychology. Furthermore, we tried to deeply understand the intrinsic neural mechanisms and psychological response of a person participating in construction engineering. The target is to improve work performance and management effectiveness from a micro-scale, and aims at more intelligent, refined, and humanized construction engineering management practices.

The remainder of this paper is organized as follows. Section 2 describes the research design and method employed in this study. In Section 3, we briefly introduce the neuropsychological mechanism of behavior, and the relationship between neuropsychology and CEM. Section 4 describes the neuropsychological methods and their application in CEM. Section 5 discusses the behavioral turn of the experimental method. Moreover, we generalize current findings of behavior research in the CEM field and try to reveal the complex correlation mechanisms of neuropsychology, individual behavior, and CEM. As a result, Section 6 summarizes the review and presents potential future trends, as well as discusses the contributions and limitations.

2. Research Design and Methods

This research is composed of quantitative bibliometric analysis and qualitative systematic literature reviews (Figure 1). On the one hand, we undertook systematic literature reviews to reveal the theory and method of neuropsychology and its implication in the CEM field. The procedures were carried out by the authors manually and the analysis was mostly qualitative description. The results of systematic literature reviews are shown in Sections 3–5, where we generalized the neuropsychological mechanisms and methods, and compared the advantages and disadvantages in detail. Then we reviewed their application in CEM, and discussed the changing methods, hot issues, and trends. Furthermore, a correlation mechanism was generated for future research.

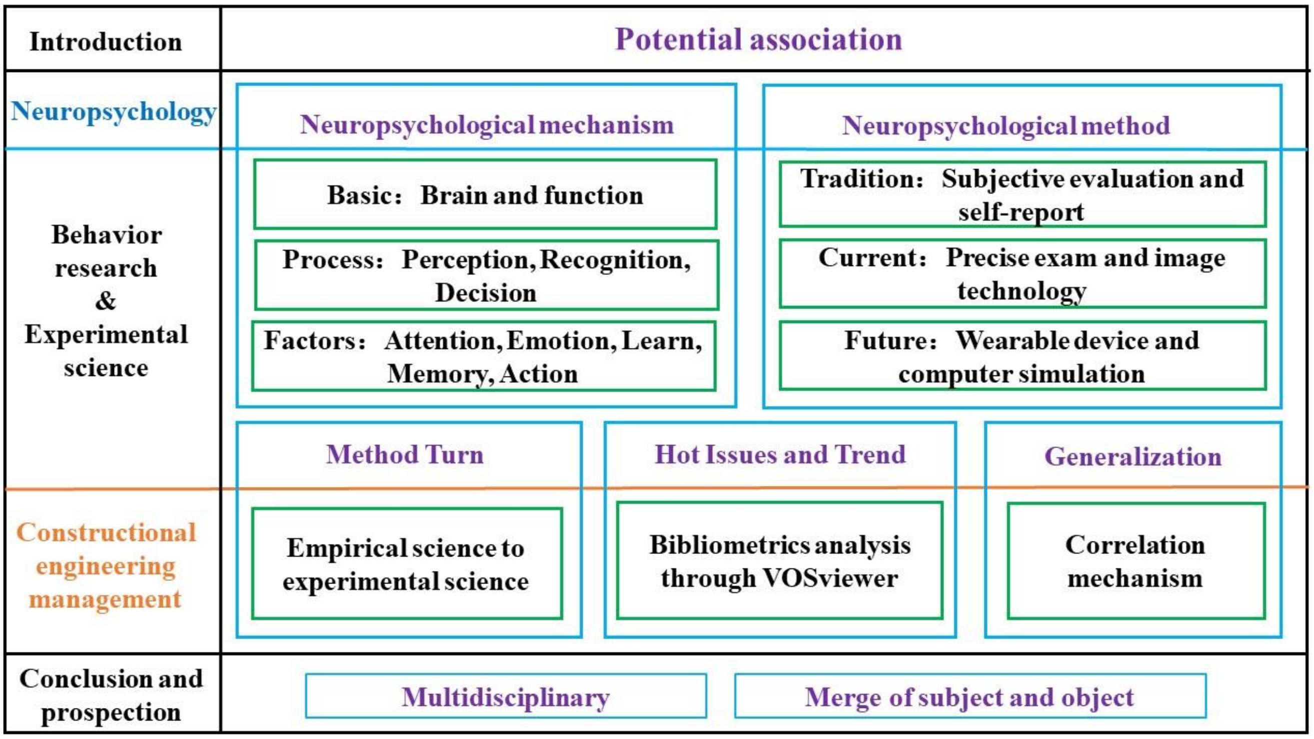

Figure 1. Research framework.

On the other hand, we employed a bibliometric analysis of 1254 studies from Web of Science using VOSviewer. The bibliometric methodology encapsulates the application of quantitative techniques on bibliometric data [10,11]. Bibliometric analysis is useful for deciphering and mapping the cumulative scientific knowledge and evolutionary nuances of well-established fields by making sense of large volumes of unstructured data in rigorous ways [12]. In this research, bibliometric study was used to survey retrospective performance and science of the behavior research in the CEM field from a neuropsychological perspective. The scope for this study was large enough with thousands of papers to warrant bibliometric analysis [12,13]. We chose a bibliographic coupling technique for performance analysis of countries (regions) and journals in the present situation and selected the co-occurrence analysis for notable words for future research directions. To collect the data, the authors consulted the literature and brainstormed to identify relevant combinations of search terms. Finally, terms were combined with construct, build, architect, engineer, manage, behavior, neuro, psychology, brain, experiment, mental, perceptive, perception, cognitive, cognition, neuroscience, and neuroergonomic. Then, the bibliometric analysis was run, and the findings are mainly reported in Section 5.

3. Neuropsychological Mechanism of Behavior

3.1. Basic Mechanism: Brain and Function

The cerebral cortex of the human brain is roughly two cerebral hemispheres in a longitudinal division. When assuming normal right-handedness, the left hemisphere controls the right side of the body, while the right hemisphere controls the left side. In cognitive processing of information, the left hemisphere shows a more sequential fashion, and the right hemisphere appears in a simultaneous manner. Therefore, the left hemisphere is better at dealing with language material, and the right side is good at planning visual space, learning, and adapting to new situations.

The sulcus also divides the brain into parts. The area anterior to the central sulcus is the frontal lobe, and posterior to the central sulcus lies the temporal, parietal, and occipital lobes. The behavioral outputs associated with the frontal lobe include motor programming, abstraction, planning, and self-regulation. The temporal lobes mainly link to the auditory channel. The parietal and occipital lobes correspond to somatosensory and visual stimuli [3,14]. As Figure 2 shows, in electroencephalogram (EEG) experiments and analysis, researchers often divide the brain into 21 electrode positions, which correspond to different function divisions by the international 10–20 electrode lead system [15]. In the EEG electrode system, odd numbers represent left and even numbers represent right. The prefix AF denotes electrodes of the frontal lobe and FC denotes electrodes between the frontal and central lobes; F, T, C, O, and P denote frontal, temporal, central, occipital, and parietal lobes; and the others such as Fp, Fz, Cz, and Pz are marker sites. For example, T8 stands for the electrode of the temporal lobe on the right side. All these channels are used for recording and describing the application locations of scalp electrodes in an EEG test. To better interpret the results, these channels can be divided into four groups: left cluster (AF3, F7, F3), right cluster (AF4, F8, F4), center cluster (FC5, FC6, T7, T8), and back cluster (P7, P8, O1, O2).

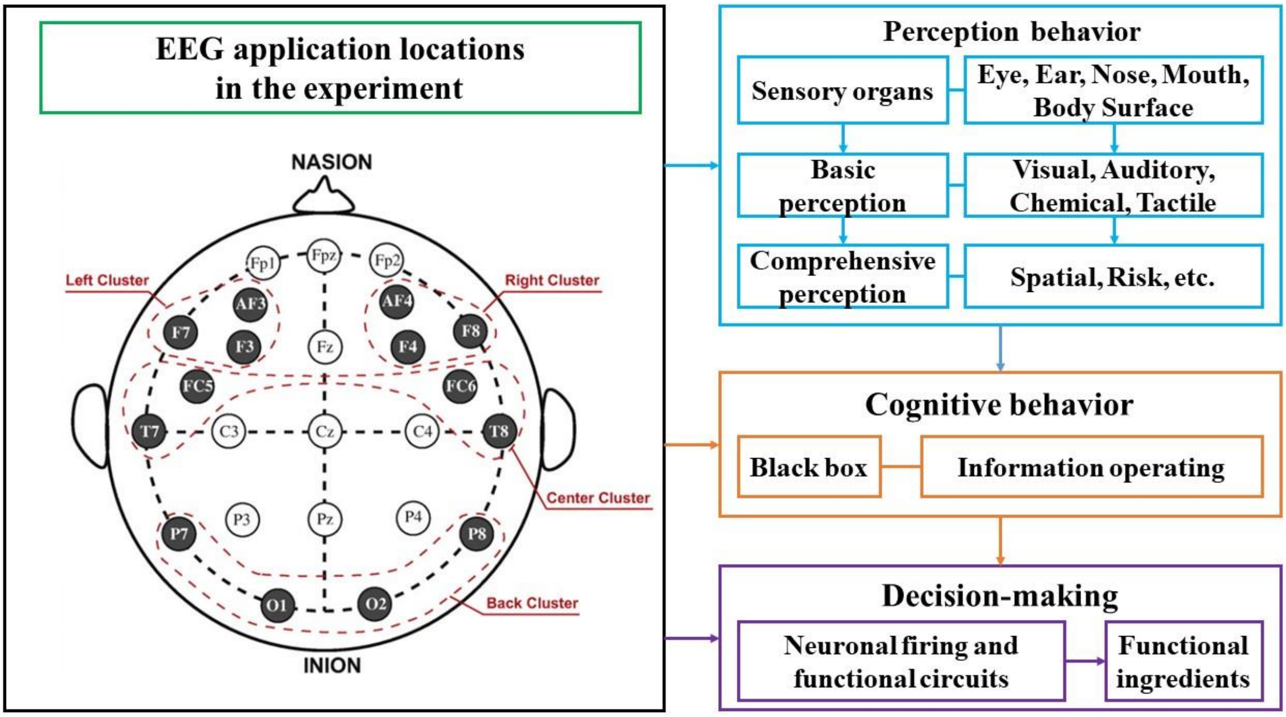

Figure 2. Neuropsychological mechanism of behavior. The electrode lead system on the left is adapted from Wang et al. (2017), and the others are drawn by the authors.

3.2. Main Process: From Sensory to Decision

After perceiving external stimuli and cognitively processing the information, the result of individual behavior usually reveals itself as decision-making in various situations and at different times. That is, human behavior usually goes through three main processes: perception, cognition, and decision-making before acting (Figure 2).

Perceptual behavior includes two main stages: sensation and perception. Sensation refers to the stage that organs receive from external stimuli. Perception indicates information understanding and explanation, including the physiological processing of the brain based on scientific information and psychological processing based on experience [16]. We can classify perception as visual perception, auditory perception, chemical perception (mainly olfactory and taste), and tactile perception (including pain). Based on sensation and perception, researchers have proposed more comprehensive perceptual concepts, such as spatial perception [17] and risk perception [18]. More studies pay attention to the connection between self and environment, behavioral individuals and physical objects, independents, and society [19]. In the preliminary design stage of construction, multiple perceptions are involved, such as visual perception when browsing contract content and design drawings, as well as auditory perception of noise, olfactory perception of air quality, and tactile perception of building materials during fieldwork. During the operating stage, equipment operators often must remark on multiple areas at the same time (the building site in front, the control panel in hand, other workers, and equipment in the surrounding areas, etc.). It is necessary to mobilize more complex perception capabilities and maintain them for a long time, such as spatial perception and risk perception [20].

Cognitive behavior also has two views: behaviorist and cognitivism. Behaviorist views take the neuropsychological mechanism as a "black-box", while cognitivism regards neuropsychological mechanisms as the progress of information working [21]. Cognitive behavior research and empirical experience provides many ideas, such as attention and interest stimuli, emotion arousal and valence, mental schema and classification, states of consciousness and memory, mindfulness, flow, and others [22,23]. Cognitive behavior also considers the interrelationships between these ideas; for example, the literature has found a strong connection between attention and memory development [24,25]. In construction engineering, researchers also explored the interrelationship between visual attention and memory experimentally and validated this in building inspections [26].

Decision-making behavior is more common in marketing research. Consumer neuroscience is defined as the application of neuroscience theories and tools to better understand human decision-making and related behaviors [4]. It is considered an interdisciplinary academic branch of marketing and neuroeconomics, including decision neuroscience, and is also supposed to be the intersection of neuroscience and consumer psychology. In fact, marketing processes are also unavoidable for construction management when requiring economic benefits. From this perspective, using relevant theories and methods in neuroscience to understand decision-making processes in construction management is also feasible. Behavior science ties into the design, analysis, evaluation, and choice of proposals, and the visual attention and information acquisition when reading a contract. Moreover, this includes the complex cognition of final discrimination [27,28]. For a more precise task, the operator's mobilization of various sensory functions of the body and the feedback of the brain's neural mechanisms would affect each control action [29].

3.3. Core Factors: Functional Ingredients

Motional behavior is implemented through the interaction of neuronal firing and functional circuits. Simplified brain regions and abstract concepts are often used to organize relevant knowledge, which means using basic functional ingredients to describe neuropsychological progress. Neural circuits of attention, emotion, and memory are ubiquitous in decision-making [30]. Neural control of learning and motion is also produced when a behavior takes place [31,32], which constitutes the main neuropsychological unit of behavior analysis [33].

Attention refers to mental engagement that focuses on specific information. When the information enters consciousness, the mind will learn about the specific items and decides whether to act [34]. Attention is also defined as the individual's choice of previous information from specific stimuli in a social context [35]. As conscious visual evidence, an approximately stable nervous system is behind attention [36]. Similarly, the neuropsychological mechanism behind visual attention is a cognitive-driven information system in construction engineering [26]. Sweany et al. (2016) have analyzed the effects of the format of engineering deliverables on craft performance based on empirical data [37]. They found the 3-dimensional computer aided design (3D CAD) model can improve the accuracy of workers' spatial cognition and the efficiency of completing preset tasks more than 2D. However, because of additional information of architectural textures, colors, and directions increases the cognitive burden of human beings, 3D models or virtual reality (VR) and augmented reality (AR), etc., are not better than traditional 2D drawings in conveying spatial information [38,39].

Learning and memory often occur at the same time because acquiring knowledge from the surrounding environment is a key condition for memory creation. At the end of the 19th century, German experimental psychologist Ebbinghaus used meaningless syllables to evaluate the effect of learning and memory and proposed the famous forgetting curve. Since the 1980s, the memory system has gained more understanding. People had divided it into sensory memory, short-term memory, and long-term memory, and further, divided short-term memory into working memory and reference memory, as well as dividing long-term memory into declarative memory and non-declarative memory (or explicit memory and implicit memory). In the field of construction engineering, limited studies focus on environmental components and spatial cognition application and lack in-depth exploration of memory [40,41].

The feature of emotion is intense sensory arousal associated with specific behavioral responses, which embodies the assessment of specific stimuli related to or irrelevant of individual or group goals [42]. Such assessment is a cognitive process that relies on the environment or proprioception. Additionally, it is taken as an attempt to maintain, establish, disrupt, or terminate connections between the individual and environment that are of great significance [18]. Therefore, Frijda (2009) argued that emotion is a process rather than a state, and that it is a subconscious event triggered by evaluating relevant stimuli in a limited dimension [43]. Moreover, this evaluation determines the strength and quality of behavioral tendencies, physiological responses, sensations, and behaviors. Current construction engineering management research has paid attention to the measurement and evaluation of emotional situations and their impact on work operations; for instance, mental fatigue [7,8] and stress [44]. Therefore, more neuropsychological analysis is still needed.

Motion control involves neural activation in multiple regions of the cerebral cortex and mass signal transmission by ganglions. Specifically, the auxiliary motor area found in the inner side of the brain controls the fingers moving [45]. When a motion needs to be completed under conditions of visual, auditory, or somatosensory feedback, the premotor cortex of the brain will be activated to extract rich representations of sensory information [46].

4. Neuropsychological Methods and Application

Before the neuropsychological technologies and methods led into behavior research, researchers widely used self-reporting methods in psychology (such as interviews and questionnaires) in behavioral research. However, the retrospective reflection of behavioral subjects is often biased [47]. To seek more reliable and accurate measurements, behavior researchers have been attempting biological psychology and neuropsychological technologies and methods, such as electrodermal response experiments in the 1920s and pupillary dilation experiments in the 1960s [48]. Afterwards, wearable devices, such as eye-tracking and heart rate measures, are becoming more acceptable because of their convenience [49]. Recently, researchers used neuroscience techniques, with electroencephalogram (EEG), functional magnetic resonance imaging (fMRI), and functional near-infrared spectroscopy (fNIRS) as the main types, to study the emotional and cognitive responses of behaving individuals. The results promote the behavior research based on neuroscience and neuropsychology [30]. There are also researchers that are pointing out that the paradigm of neuropsychology is shifting to digital neuropsychology and will form a high-dimensional neuropsychological assessment through simulation computing [50].

4.1. Tradition: Subjective Evaluation and Self-Report

Early neuropsychological assessments rely primarily on evaluation and self-report methods. They can often be categorized as qualitatively or quantitatively focused. Qualitative assessments are derived from approaches of behavioral neurology and rely on intuitive insight, which requires considerable knowledge of neurology [2]. Compared to the subjective evaluation of the evaluator, another perspective is the oral retrospective statements, such as in-depth interviews, ladder interviews, and focus interviews or written language statements of open-ended questionnaires based on self-knowledge. Quantitative assessments are attributed to clinical neuropsychology, emphasizing standardized psychometric tests. Quantitative analysis has formed various scales and tests, including the Wechsler Intelligence Scale (WISC), Minnesota Multiphasic Personality Inventory (MMPI), Tactual Performance Test (TPT), Finger-tapping Test (FT), Speech Sounds Perception Test (SSPT), Rhythm Test (RT), Train Making Test (TMT), and sensory perceptual examination, etc.

In the spatial perception and cognitive behavior closely related to architecture and construction, researchers have put forward and applied the cognitive map [51]. In practice, the cognitive map means “maps in the mind” and hypothetical constructions of map metaphors and is the visual expression of space. Researchers have asked people to express spatial form in the mind using painting. Passini (1984) pointed out in more detail that cognitive maps reflect people’s cognitive and behavioral abilities in space [52]. This ability is based on three direct manifestations—information processing, decision-making, and task execution—reflecting the solving ability in response to spatial problems. Considering the differences in psychological comfort, spatial anxiety, and behavioral dependence, relevant staff should have higher spatial perception and expression skills [53–55]. Research on escape behavior during fire drills has also shown that people with higher spatial abilities are better able to understand building structures and symbolic representations, which means higher building space design, disaster prevention, and condition controlling capabilities [56,57].

4.2. Current: Precise Exam and Image Technology

There are three major spectrum techniques for precise examinations and images in neuropsychological diagnosis: physical neurological exam (PNE), computed axial tomography scan (CT), and EEG. PNE needs a standard physical examination (usually lasting more than 20 min) and a detailed medical history, so it is usually performed by medical professionals [58]. CT combines a computer and traditional X-ray machine to take brain pictures from multiple locations through X-ray. Then, they are transmitted to a computer for data conversion and analysis, resulting in a visualization of the density of different brain tissues on a cathode-ray screen. However, despite CT having higher cost-effectiveness, the false-negative errors still have a 50% occurrence, and so it needs to be combined with other measurements.

EEG acquires brain wave data by attaching electrodes to specific regions of the frontal, temporal, parietal, and occipital lobes. It can interpret brain activity based on brain waves, and so it is more closely related to the neural activity in the brain [59]. However, it also should be noted that since 15–20% of the normal population will have abnormal EEGs, the results of EEG analysis may have false-positive errors. An EEG experiment found that noise can affect the information machining process of construction workers [60]. Under the influence of high noise, construction workers will have higher self-depletion and show a behavioral tendency to seek rewards. The result means the workers need a longer response time for behavioral decision-making, increasing the risk of hazardous behavior.

4.3. Future: Wearable Devices and Computer Simulation

Neuropsychologists and behaviorists in the digital age have increasing access to emerging technologies. Relying on the technological advancement of portable wearable devices, behavioral research is no longer limited to the laboratory environment. Researchers can conduct behavioral experiments in real scenes and the real world, and it has been used in some fields such as tourism, marketing, transportation, etc. [49].

Eye-tracking can explain the neuropsychological mechanism of visual perception behavior by recording the process of eye movement. Existing research usually visualized tracking results through a heat map and trajectory map to illustrate potential neuropsychological responses functionally and effectively. Eye-tracking research has developed from the initial observation of appearance characteristics to accurate measurement records and formed modern technology to analyze eye movement patterns. It has become an important method in the research of spatial cognition, map cognition, map systems, and other fields [61]. In construction engineering and management, wearable devices are also applied in research of mental fatigue, hazard detection [8,62], fairness perception [27,28], and performance behavior [63] of construction contractors in contract signing.

Wearable and wireless EEG device systems can quantitatively and automatically assess the attention level of construction workers by recording and analyzing signals of the brain. EEG signal characteristics, such as frequency, power spectral density, and spatial distribution, can effectively reflect and quantify the perceived risk level of construction workers. Meanwhile, the lower gamma frequency band and left frontal lobe EEG cluster directly and appreciably show the worker's state of alertness [15]. Compared to fMRI and fNIRS, EEG provides higher temporal resolution but lacks spatial resolution [64–66]. The sampling frequency of fNIRS is relatively low (less than 20 Hz), but the spatial resolution is higher, which is crucial for monitoring brain regions associated with mental loading [67,68]. In empirical research, Shi et al. (2020) built a virtual industrial maintenance scenario to present a human–subject experiment, and to examine the impact of information format on the performance of a pipe maintenance task, as well as the implications of cognitive costs in both working memory development (information encoding) and retrieval (information recalling) [44]. The research aimed to establish an evaluation system for predicting engineering performance and then inspire the design of personalized training systems driven by cognition in construction engineering.

Moreover, computational simulation is considered a high-dimensional technique of neuropsychology in the continual development of VR, AR, and mixed reality (MR). The behavioral and social science initiative of the National Institutes of Health (NIH) highlights the developing scientific and technological potentials (such as new sensors), and to enhance the characterization of neurocognitive, behavioral, emotional, and social understanding. Jolly and Chang (2019) considered that neuropsychological assessments that are two-dimensional may previously have had a flatland fallacy [69]. They suggest that this fallacy can be overcome by formalizing psychological theories into computational models, making it capable for predicting cognition and behavior precisely. Simulating the parallel, reciprocal, and iterative interactions between the environment and neural function of complex behavior can enhance the ability of actual operations [50]. Building Information Modeling (BIM) is a beneficial attempt at visualization and predictability in construction engineering, as well as Heritage Building Information Modeling (HBIM) and BIM+. However, such models are still limited to the simulation and calculation of architecture or building substance, while the behavior simulation and more subtle neural mechanisms are still difficult to achieve.

As Table 1 shows, whether it is an objective measurement dominated by technical tools or a subjective judgment dominated by self-report, each method has its advantages and limitations. There is a growing consensus that researchers using neuroscientific methods and devices must have qualitative knowledge or experience of the phenomenon. Then, the researchers can reasonably interpret neuropsychological indicators and the signals they represent. As Plassman et al. (2015) claim, the fullest explanation of consumer and managerial behavior requires a combination of neuroscientific measurements and subjective explanations [4]. When combining the methods, researchers will draw the most productive and profound conclusions, as the advantages of one method outweigh the disadvantages of the other.

Table 1. Comparison of neuropsychological methods.

Methodology	Specific Method	Advantage	Disadvantage
Self-report	Interview	Richer explanatory information	Incomplete authenticity
	Retrospective statement	Richer explanatory information	Reflection bias
	Cognitive map	Richer explanatory information	Reflection bias
	Questionnaire	Richer explanatory information	Subjectivity of measurements
Biological measurement	Electrodermal response	Objective and accurate	Weak stimulus response
	Pupillary dilation	Objective and accurate	Lack of criteria for expansion
Spectral imaging	PNE	Sufficient	Long duration, high profession
	CT	Comprehensive angle	Cost effectiveness, false-negative errors, invasiveness
	EEG	Non-invasive, high temporal resolution	False-positive errors
	fMRI	Non-invasive, slice image of any angle	Low spatial resolution
	fNIRS	Non-invasive, high spatial resolution	Low sampling frequency
Wearable devices	EEG	Convenience, accuracy, visible	Low spatial resolution
	Eye-tracking	Convenience, accuracy, visible	Limited visual distance, vision requirements
Computational simulation	BIM	Structural modeling, superfine	Difficult to simulate neural procedure behind behavior
	Simulation Platform	Systematic, processed	Difficult to simulate neural procedure behind behavior

5. Behavior Research in Construction Engineering Management

5.1. Behavioral Turns of Method: Neuropsychological Experiment

In addition to focusing on economic issues such as economic benefits and cost control, engineering issues such as construction technology and schedule control must also be given attention. Construction engineering and management also pays attention to management issues such as organizational systems and contract signing. This shows the research content has gradually shifted from focusing on objects such as equipment, materials, and structures, to focusing on humans; that is, the behavioral response of individuals or organizations to system design and management processes. However, single and traditional methods inevitably have shortcomings in data acquisition or measurement, and it is difficult to infer the influencing factors of management and decision-making.

Through scientific design and critical control, behavioral analysis and experimental methods can improve the reliability of data and the interpretability of research results. Figure 3 summarizes the general process of behavioral experiments and neuropsychological experiments. Applicable experimental designs in construction engineering and management include single-station passive observation, contrast experiments, and randomized experiments [70]. In practical application, these experiments should ensure the controllability of the environment, the systematisms of the research content, and the predictability of the research conclusions. Few Chinese researchers also prefer to apply the behavioral experiment to construction engineering and management. For example, Li et al. (2012) took computational experiments as a research method to discuss the multistage group incentive problem when considering the fairness perception of individual contractors [71]. To sum up, research methods applied in construction engineering and management have transitioned from framed qualitative research to model-based quantitative research. However, the application of neuropsychological experimental methods is still in infancy [72].

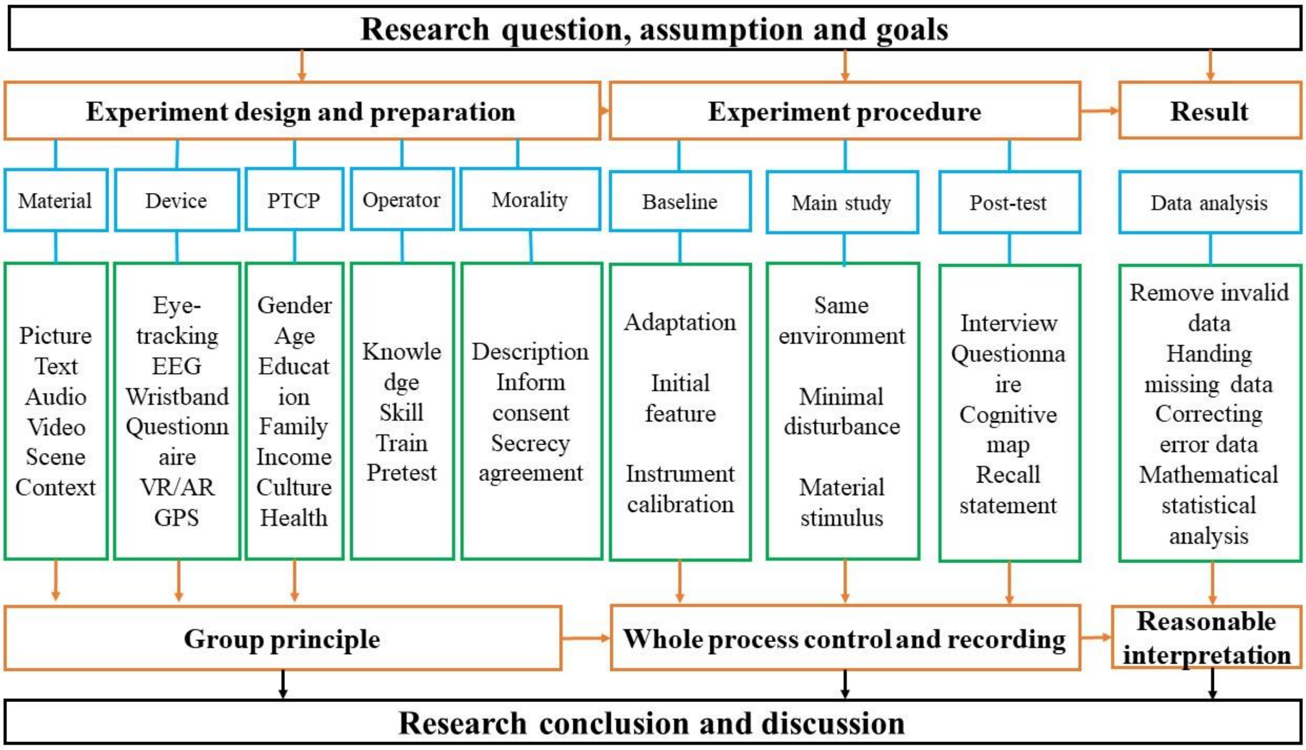

Figure 3. Neuropsychological experiment process. Drawn by the authors.

5.2. Bibliometric Analysis: Countries (Regions) and Hot Issues

5.2.1. Countries (Regions) Cluster and Timing Progress

By choosing bibliographic coupling as the analysis type and countries as the analysis unit, with the minimum number of documents as six, forty countries or regions meet the thresholds. The countries or regions of publications are shown in Figure 4, and the ten countries (regions) with the most publications are shown in Table 2. From the results, researchers from Taiwan, China have begun to pay more attention to the neuropsychological mechanisms of individual behavior in CEM earlier and have published some achievements. Then, American researchers have focused on this field and have published a large number of achievements. After that, researchers from Australia, Canada, England, France, and Spain also began to get involved in neuropsychological research and published some achievements. In these countries (regions), Australia has the most publications. Indian scholars then paid attention to this research topic and carried out some related research. In the most recent time period, Italian researchers also realized the important role of neuropsychology in revealing behavioral mechanisms and carried out lots of research in the CEM field. At the same time, Chinese scholars attended to this field; these researchers tried to introduce neuropsychological theories and methods into construction engineering management and its behavioral research, and thus a large number of achievements have been published.

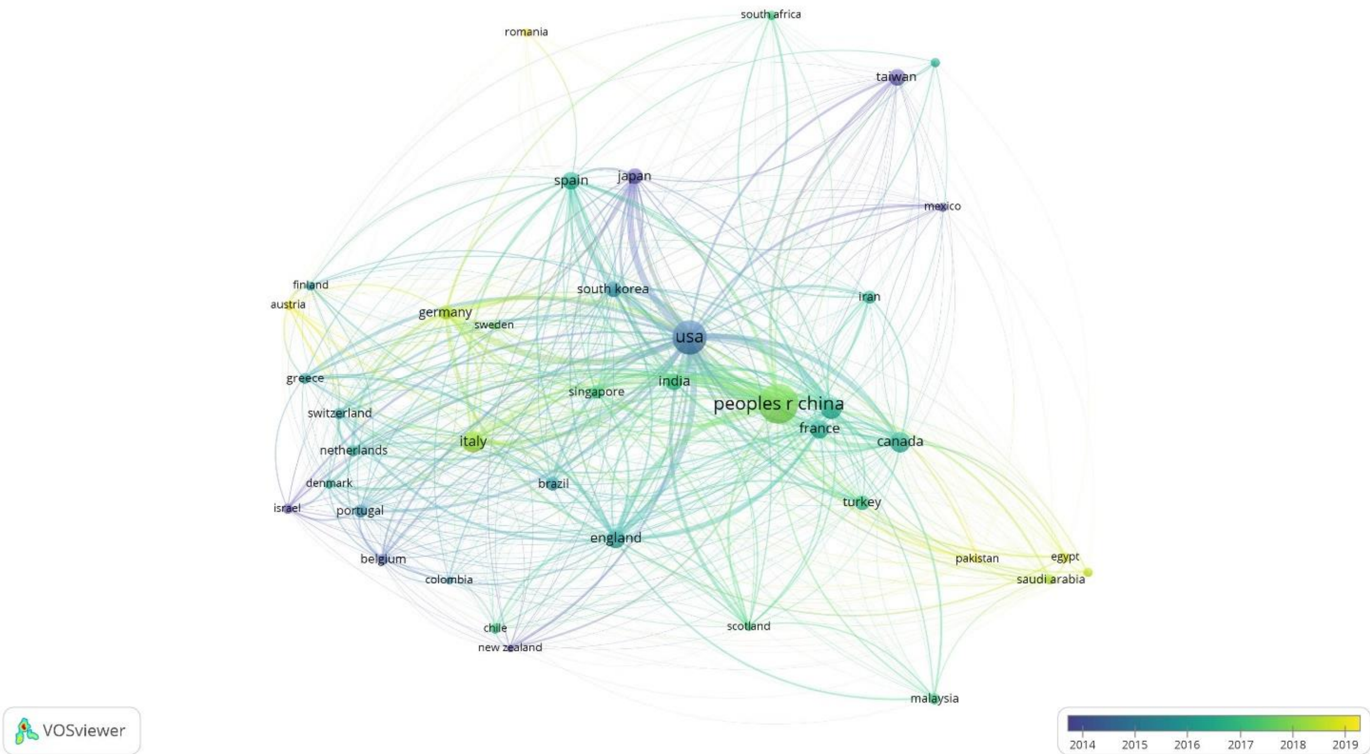

Figure 4. Countries (regions) and timing progress. The "Taiwan" in this figure refers to "Taiwan, China".

Table 2. Distribution and timing progress examples of existing publications.

Countries (Regions)	Average Publication Year	Publication Count
China	2018	370
USA	2015	263
Australia	2016	79
Italy	2018	72
Canada	2016	64
England	2016	56
France	2016	52
India	2017	48
Spain	2016	48
Taiwan, China	2013	38

5.2.2. Hot Issues and Timing Progress

By selecting co-occurrence as an analysis type and keywords as the analysis unit, with the minimum number of occurrences of a keyword as six, 314 of 7443 keywords meet the thresholds. These keywords and their average publication year are shown in Figure 5, and the ten keywords with the most occurrences are shown in Table 3. From the results, "design" is the keyword that occurred earlier at the average publication year of 2015. Then, "model", "construction", and "simulation" occurred frequently near 2016. Scholars were beginning to seek more digital technology and simulation methods in construction research. Then in 2017, "behavior" became the most occurrent keyword, which suggests that behavior research in the CEM field is fresh and hot in recent years. At this period, "performance", "management", "system", "strength", and "impact" are also important keywords, but performance and management occurred much more. It means that researchers have paid more attention to the people-oriented perspective and cared more about the management of the behavior of individuals, such as performance and strength.

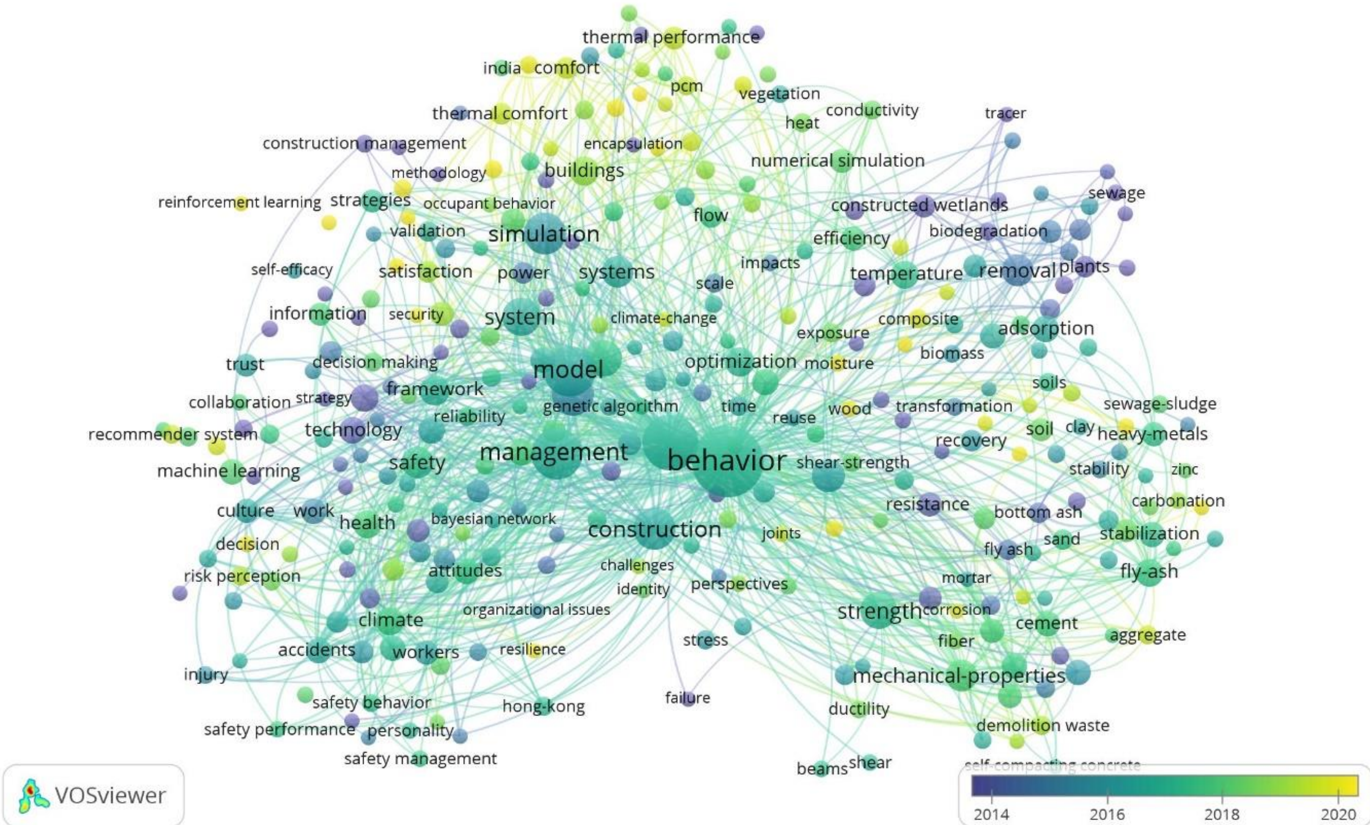

Figure 5. Keywords and timing progress.

Although keywords related to neuropsychology such as risk perception, stress, satisfaction, self-efficacy, stress, attitude, injury, and health are also present in the figure, they are all with little occurrence. This clearly reflects that the application of neuropsychology in construction engineering management and its behavior research is still very insufficient. To sum up, current research on construction engineering management emphasized the analysis of behavior and has shown a tendency to focus on behavioral subjects, but the related theories and methods of neuropsychology are still very lacking in this field. For some research, although neuropsychological theories and methods have been applied, construction engineering management plays a role as a mere research context. However, in interdisciplinary research, the comparative balance between different disciplines is the premise to accomplish complementary advantages and knowledge exchange for interdisciplinary research.

Table 3. Keywords and timing progress examples.

Keyword	Average Publication Year	Count
behavior	2017	261
performance	2017	139
management	2017	106
model	2016	105
construction	2016	68
simulation	2016	67
design	2015	63
system	2017	51
strength	2017	47
impact	2017	45

5.3. Generalization: Complex Correlation Mechanism

Construction engineering management studies provide the means and methods to examine the physical world and organizational management to improve the validity and efficiency of management in the construction industry. Although relevant research is very limited, scholars have explored employing neuropsychology in the behavioral research of construction engineering management. To better understand and reveal behavior mechanisms in CEM, we provide a recap in Table 4 with the examples of CEM behavioral studies and their key methods and findings in the last five years. The main content of CEM behavioral studies includes hazard recognition, construction equipment-related accidents and safety management, mental fatigue, physical fatigue, spatial and work memory, building inspection, engineering information formats, operations and performances, working skills, and others. The research design of CEM behavioral studies is mainly based on experiments with different simulated conditions, such as various task settings and scenarios. The methods are composed of data collection technology and analysis methodology. Neuropsychological methods are usually used for data collection such as NIRS, eye-tracking devices, and wearable EEG systems. Some self-report methods may also be added for subjective data collection, such as questionnaire surveys or cognitive mapping. Information technology and statistical methods are normally taken for data analysis, such as some deep learning or machine learning of information technology, linear discriminant analysis, or MANOVA analysis of statistical methods.

Based on the review of relevant literature findings, this paper tries to establish a behavioral correlation mechanism in CEM from the perspective of neuropsychology. Although this mechanism may be difficult to cover in all research results, it can still intuitively demonstrate how neuropsychological mechanisms affect human behavior and ultimately play a role in CEM. As Figure 6 shows, current neuropsychological research on behavior mainly starts from visual behavior, and the main content of CEM is "risk identification" and "performance evaluation and prediction". For example, Wang et al. (2017) found that EEG signal properties such as frequency, power spectrum density, and spatial distribution can effectively reflect the workers' perceived risk level [15]. Shi et al. (2020) found that stressful training has a strong impact on neural connectivity and gaze movement patterns, which further affect final performance [44]. Some research conclusions clearly point out specific indicators and their positive or negative effects. For example, Shi, Du, & Ragan (2020) found a positive relationship between visual attention (fixation time) and spatial memory [26]. However, many studies only found correlations between certain neuropsychological causes and behavioral outcomes. It is difficult to explain more detailed action paths, degrees, and valence, especially when the complex nervous system of the brain is involved.

Table 4. Current research and main findings.

Authors	Year	Main Content	Design	Method	Findings
Zhou et al. [73]	2021	Neurophysiological mechanics of hazard recognition	Multiple HR tasks experiment in laboratory setting and hemodynamic responses	NIRS; Fisher score; linear discriminant analysis	Left PFC was more engaged in HR
Li et al. [62]	2020	Operator's mental fatigue; construction equipment-related accidents	Simulated excavator operation experiment with wearable eye-tracking devices	TICC method; Supervised learning algorithms; Support Vector Machine	Different levels of mental fatigue had varying effects on the operator's productivity and safety performance
Shi, Du, & Ragan. [26]	2020	Visual attention; spatial memory; building inspection	Human–subject experiment (2D, 3D, VR) with building inspection task	Human–subject experiment; Eye-tracking	There is a positive relationship between visual attention (fixation time) and spatial memory
Shi, Du, & Worthy. [29]	2020	Engineering information formats; construction operations; work memory	Participants reviewed the operational instructions for a pipe maintenance task, performed the task from memory	Human–subject experiment; cognitive load analysis with survey	Larger pupil dilation during encoding, indicative of successful working memory formation, was associated with better subsequent performance
Shi, Zhu, Mehta, & Du. [44]	2020	Industrial shutdown maintenance; training outcome under stress	A virtual reality (VR) system integrated with the eye-tracking function to simulate the operation scenarios	Virtual reality experiment; fNIRS	Stressful training has strong impact on neural connectivity and gaze movement patterns, which further effect final performance
Xing et al. [7]	2020	Physical and mental fatigue of construction workers; safety management	Manual handling tasks for physical fatigue statuses; cognition-required risk identification task for mental fatigue, wearable EEG sensor fatigue detection and measurement	Pilot experimental method	High physical fatigue could accelerate the induction of mental fatigue; more attention sources were required during the intensive manual handling tasks
Hasanzadeh et al. [9]	2017	Construction workers' hazard identification skills	An experiment was designed to track eye movements of construction workers while they searched for hazards in randomly ordered construction scenario images	Eye-tracking experiment; MANOVA analysis	Hazard identification skills significantly impacted workers' visual search strategies; fixation count can discriminate workers with high hazard-identification skills and at-risk workers
Wang et al. [15]	2017	Workers' attention and vigilance in construction activities	On-site experiment to analyze the EEG signal patterns when construction workers avoid different obstacles in their tasks	Wearable EEG system; on-site experiment	EEG signal properties such as frequency, power spectrum density, and spatial distribution can effectively reflect the workers' perceived risk level

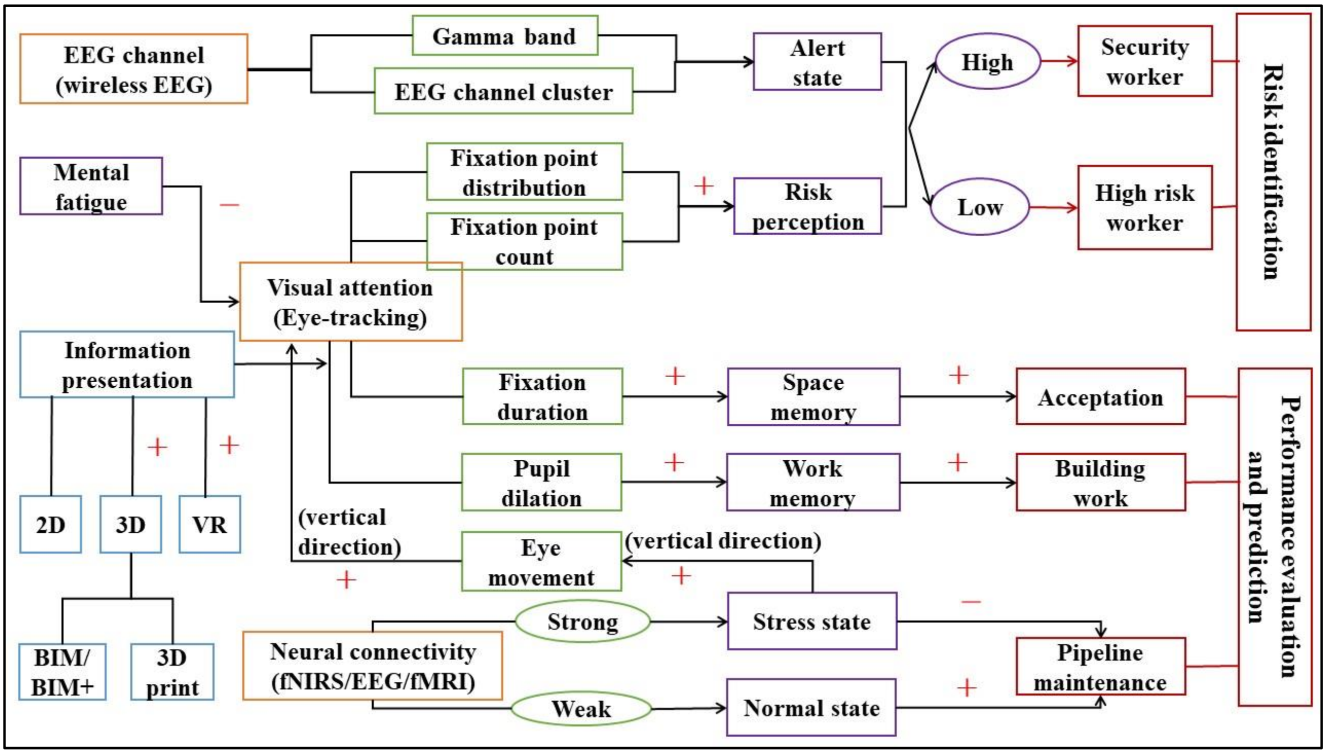

Figure 6. Complex behavioral associations. "+" indicates enhancing or positive promotion, "−" indicates weakening or negative inhibition, "unsigned" paths represent correlation only.

Eye-tracking research on visual behavior has successfully found that specific eye-movement indicators have an indicative effect on certain perceptions and cognitive behaviors, resulting in improved or weakened effects. For example, the distribution and number of fixation points can positively enhance risk perception, to identify whether the participant can keep a high level of safety at work. Moreover, gaze time and pupil dilation can positively promote the participant's memory of space and task content, respectively, and then positively promote the acceptance or building work of construction, and supremely help predict behavioral performance. It is worth noting the cognitive state of the participant may not be the result of neuropsychological effects, but the cause of different neuropsychological manifestations. For instance, mental fatigue will negatively affect workers' visual attention.

In addition, the results in the figure also show the effect of stress on eye movement. When participants are under high stress, their eye movements will improve, and their visual attention will be more concentrated in the vertical direction. It will directly affect the acquiring of visual information. Relevant research shows that in pipeline maintenance work of construction engineering, when the pressure load for the staff is large, the work's precision will reduce. The conclusion in the diagram also shows the influence of information presentation (such as the renderings of construction) on visual attention. As 3D presentations influence the fixation time of visual attention, there is research that found that 3D presentations, such as 3D images, BIM models, 3D printing and virtual reality technologies, are better than 2D planes in rendering effect.

In general, conducting behavioral research in CEM from the perspective of neuropsychology reflects a multidisciplinary research trend. The research in this field involves three complex dimensions: the brain and nervous system, the construction engineering management system, and individual and behavioral research (see Figure 7). For the research field, research between the brain and nervous system and construction engineering, or between the brain and nervous system and individual behavior, is mainly exploring the internal causes of external response. Research between behavior and CEM is mainly focused on the impact on performance. The essence is the result of interaction among the internal neuropsychological mechanisms, the external behavioral mechanisms, and the construction engineering management mechanism. Therefore, the core of this multidisciplinary field is the effect paths among three mechanisms. As for the science of construction engineering management, knowledge from the four disciplines of psychology, neuroscience, management, and architecture should be absorbed. Moreover, the intersection between four disciplines needs to be noticed with an interaction in mind of combining the subjective and objective, the physical and mental, and the micro and macro.

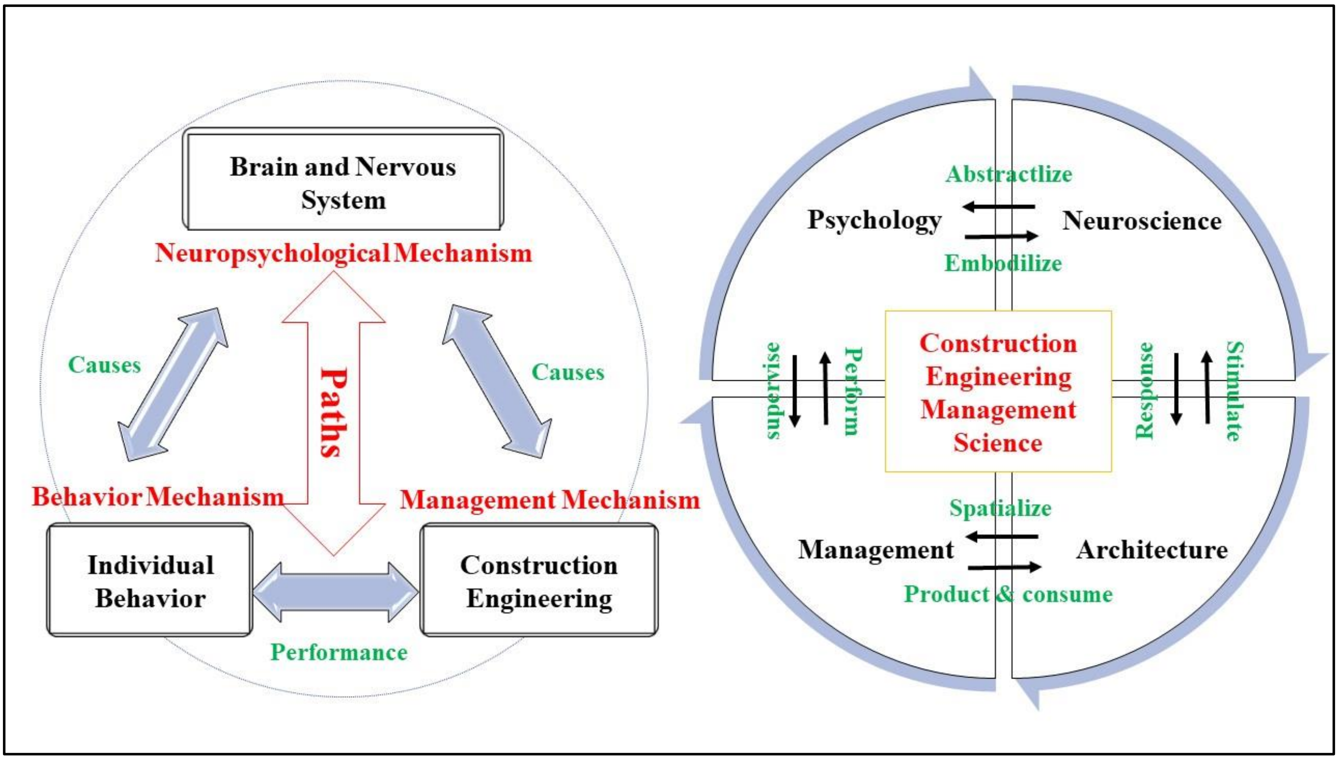

Figure 7. Interdisciplinary interrelationship.

6. Conclusions and Prospection

This paper aimed to reveal the behavioral causes, behavioral performance, and the action paths of the relevant individuals in CEM. Although the research on CEM and its behavior based on neuropsychological theories and methods is still insufficient in volume and incomplete in content, the predictability of its development prospects is substantively existing. The current method has become increasingly rich, including experiments, surveys and observational studies, modeling and simulations, theory building, and case studies and their various subtypes. Moreover, some researchers are often using more than one method, which is both an opportunity and a challenge for construction engineering and management research [70]. Introducing new theories and new technology methods for any scientific research needs to ensure rigorous verification at every step. The derived results need both academics and practice to test, and then such research can be advanced with the help of new knowledge. Finally, related research can filter to daily use, to achieve the goal of providing welfare to society.

In conclusion, this paper attempted to sort out the behavioral research in construction engineering management from the perspective of neuropsychology: on the one hand, to strengthen the understanding of neuropsychological theories, techniques, and methods, and on the other hand, to explore the more refined internal relationship between construction engineering management and behavior from the perspective of micro-individuals. Based on this knowledge, this paper tried to summarize the specific methods and conclusions that can be used for reference in applying neuropsychology in the research and practice of construction engineering management.

The contribution of this paper is the carrying out of a qualitative sorting and quantitative analysis based on the common goal of multidisciplinary crossover and integration. The results can provide effective references for revealing the existing conclusions, available methods, and future trends in this disciplinary field. In detail, this review from the perspective of neuropsychology, focused on the working mechanism of the human brain and nervous system, individual behavior, and construction engineering, is close to the needs of CEM practice. Starting from the human body, it can assist managers to formulate more refined and humanized measures to improve the efficiency and safety of CEM. Meanwhile, a more accurate analysis of the working mechanism between the brain and behavior provided the reference for improving benefits of CEM. To some extent, it can also avoid ineffectiveness and inefficiency in CEM and promotes the development of sustainable construction production and consumption. Lastly, the review of human factors' methods and research also clarifies the human behavioral mechanism, which has considerable reference for designing and building a people-oriented livable city.

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References

1. Kalat, J.W. *Biological Psychology*, 13th ed.; Cengage Learning: Singapore, 2015.
2. Horton, A.M.J.; Wedding, D.; Phay, A. A current perspective on assessment of and therapy for brain-damaged individuals. In *Applied Techniques in Behavioral Medicine (59–85)*; Golden, C.J., Graber, B., Strider, F., Strider, M.A., Alcaparres, S.S., Eds.; Grune & Stratton: New York, NY, USA, 1981.
3. Horton, J.A.M.; Miller, W.G. Neuropsychology and behavior therapy. *Prog. Behav. Modif.* **1985**, *19*, 1–55. [CrossRef] [PubMed]
4. Plassmann, H.; Venkatraman, V.; Huettel, S.; Yoon, C. Consumer neuroscience: Applications, challenges, and possible solutions. *J. Mark. Res.* **2015**, *52*, 427–435. [CrossRef]
5. Adolphs, R. Conceptual challenges and directions for social neuroscience. *Neuron* **2010**, *65*, 752–767. [CrossRef] [PubMed]
6. Camerer, C.; Loewenstein, G.; Prelec, D. Neuroeconomics: How neuroscience can inform economics. *J. Econ. Lit.* **2005**, *43*, 9–64. [CrossRef]
7. Xing, X.; Zhong, B.; Luo, H.; Rose, T.; Li, J.; Antwi-Afari, M.F. Effects of physical fatigue on the induction of mental fatigue of construction workers: A pilot study based on a neurophysiological approach. *Autom. Constr.* **2020**, *120*, 103381. [CrossRef]
8. Li, J.; Li, H.; Wang, H.; Umer, W.; Fu, H.; Xing, X. Evaluating the impact of mental fatigue on construction equipment operators' ability to detect hazards using wearable eye-tracking technology. *Autom. Constr.* **2019**, *105*, 102835. [CrossRef]
9. Hasanzadeh, S.; Esmaeili, B.; Dodd, M.D. Impact of construction workers' hazard identification skills on their visual attention. *J. Constr. Eng. Manag.* **2017**, *143*, 4017070. [CrossRef]
10. Broadus, R.N. Toward a definition of "bibliometrics". *Scientometrics* **1987**, *12*, 373–379. [CrossRef]
11. Pritchard, A. Statistical bibliography or bibliometrics. *J. Doc.* **1969**, *25*, 348.
12. Donthu, N.; Kumar, S.; Mukherjee, D.; Pandey, N.; Lim, W.M. How to conduct a bibliometric analysis: An overview and guidelines. *J. Bus. Res.* **2021**, *133*, 285–296. [CrossRef]
13. Ramos-Rodríguez, A.-R.; Ruíz-Navarro, J. Changes in the intellectual structure of strategic management research: A bibliometric study of the *Strategic Management Journal*, 1980–2000. *Strateg. Manag. J.* **2004**, *25*, 981–1004. [CrossRef]

14. Horton, A.M., Jr.; Howe, N.R. Behavioral neuropsychology and the traumatic brain injured adult: A case study. In Proceedings of the 5th Annual Post-Graduate Course on the Rehabilitation of the Brain-Injured Adult (18–19); Virginia Commonwealth University: Richmond, VA, USA, 1981.
15. Wang, D.; Chen, J.; Zhao, D.; Dai, F.; Zheng, C.; Wu, X. Monitoring workers' attention and vigilance in construction activities through a wireless and wearable electroencephalography system. *Autom. Constr.* **2017**, *82*, 122–137. [CrossRef]
16. Solso, R.L.; MacLin, M.K.; MacLin, O.H. *Cognitive Psychology*; Pearson Education New Zealand: Auckland, New Zealand, 2005.
17. Foreman, N.; Gillett, R. *A Handbook of Spatial Research Paradigms and Methodologies*; Psychology Press: London, UK, 1997; Volume 2.
18. Perlman, A.; Sacks, R.; Barak, R. Hazard recognition and risk perception in construction. *Saf. Sci.* **2014**, *64*, 22–31. [CrossRef]
19. Devlin, A.S. *Mind and Maze: Spatial Cognition and Environmental Behavior*; Praeger Publishers/Greenwood Publishing Group: Westport, CT, USA, 2001.
20. Wagstaff, A.S.; Lie, J.S. Shift and night work and long working hours-a systematic review of safety implications. *Scand. J. Work. Environ. Health* **2011**, *37*, 173–185. [CrossRef] [PubMed]
21. Skavronskaya, L.; Scott, N.; Moyle, B.; Le, D.; Hadinejad, A.; Zhang, R.; Gardiner, S.; Coghlan, A.; Shakeela, A. Cognitive psychology and tourism research: State of the art. *Tour. Rev.* **2017**, *72*, 221–237. [CrossRef]
22. Langer, E.J. Matters of mind: Mindfulness/mindlessness in perspective. *Conscious. Cogn.* **1992**, *1*, 289–305. [CrossRef]
23. Nevid, J.S. *Essentials of Psychology: Concepts and Applications*; Cengage Learning: Boston, MA, USA, 2021.
24. Awh, E.; Anllo-Vento, L.; Hillyard, S.A. The role of spatial selective attention in working memory for locations: Evidence from event-related potentials. *J. Cogn. Neurosci.* **2000**, *12*, 840–847. [CrossRef]
25. Awh, E.; Vogel, E.K.; Oh, S. Interactions between attention and working memory. *Neuroscience* **2006**, *139*, 201–208. [CrossRef]
26. Shi, Y.; Du, J.; Ragan, E. Review visual attention and spatial memory in building inspection: Toward a cognition-driven information system. *Adv. Eng. Inform.* **2020**, *44*, 101061. [CrossRef]
27. Yan, L.; Zeng, C.; Guo, L.; Li, Z. Formation of the contractor's justice perception based on eye movement experiment. *Sci. Res. Manag.* **2020**, *41*, 219–227. (In Chinese) [CrossRef]
28. Yan, L.; Guo, L.; Zeng, C.; Li, Z. Study on the Multi-dimensional Structure and Content of the Contract Reference Point in Construction Project Situation: Based on Content Analysis and Eye Movement Experiment. *Manag. Rev.* **2020**, *32*, 179–192. (In Chinese)
29. Shi, Y.; Du, J.; Worthy, D.A. The impact of engineering information formats on learning and execution of construction operations: A virtual reality pipe maintenance experiment. *Autom. Constr.* **2020**, *119*, 103367. [CrossRef]
30. Shaw, S.D.; Bagozzi, R.P. The neuropsychology of consumer behavior and marketing. *Consum. Psychol. Rev.* **2018**, *1*, 22–40. [CrossRef]
31. Bliss, T.V.; Lømo, T. Long-lasting potentiation of synaptic transmission in the dentate area of the anaesthetized rabbit following stimulation of the perforant path. *J. Physiol.* **1973**, *232*, 331–356. [CrossRef] [PubMed]
32. Jeannerod, M. *The Cognitive Neuroscience of Action*; Blackwell Publishing: Oxford, UK, 1997.
33. Garrett, B.L. *Brain & Behavior: An Introduction to Biological Psychology*; SAGE Publications: New York, NY, USA, 2010.
34. Terranova, T. Attention, economy and the brain. *Cult. Mach.* **2012**, *13*, 1–19.
35. Gazzaley, A.; Cooney, J.W.; Rissman, J.; D'Esposito, M. Top-down suppression deficit underlies working memory impairment in normal aging. *Nat. Neurosci.* **2005**, *8*, 1298–1300. [CrossRef] [PubMed]
36. Duchowski, A.T.; Duchowski, A.T. *Eye Tracking Methodology: Theory and Practice*; Springer: Berlin, Germany, 2017.
37. Sweany, J.; Goodrum, P.; Miller, J. Analysis of empirical data on the effects of the format of engineering deliverables on craft performance. *Autom. Constr.* **2016**, *69*, 59–67. [CrossRef]
38. Richardson, A.E.; Montello, D.R.; Hegarty, M. Spatial knowledge acquisition from maps and from navigation in real and virtual environments. *Mem. Cogn.* **1999**, *27*, 741–750. [CrossRef]
39. Verghote, A.; Al-Haddad, S.; Goodrum, P.; Van Emelen, S. The effects of information format and spatial cognition on individual wayfinding performance. *Buildings* **2019**, *9*, 29. [CrossRef]
40. Kondyli, V.; Bhatt, M.; Hartmann, T. Precedent based design foundations for parametric design. *Adv. Comput. Des.* **2018**, *3*, 30. [CrossRef]
41. Kondyli, V.; Bhatt, M. Rotational locomotion in large-scale environments: A survey and implications for evidence-based design practice. *Built Environ.* **2018**, *44*, 241–258. [CrossRef]
42. Niedenthal, P.M.; Brauer, M. Social functionality of human emotion. *Annu. Rev. Psychol.* **2012**, *63*, 259–285. [CrossRef] [PubMed]
43. Frijda, N.H. Emotion experience and its varieties. *Emot. Rev.* **2009**, *1*, 264–271. [CrossRef]
44. Shi, Y.; Zhu, Y.; Mehta, R.K.; Du, J. A neurophysiological approach to assess training outcome under stress: A virtual reality experiment of industrial shutdown maintenance using Functional Near-Infrared Spectroscopy (fNIRS). *Adv. Eng. Inform.* **2020**, *46*, 101153. [CrossRef]
45. Chee, B.P.; Lim, A.; Chia, J.C.; Teh, M. Soft tissue chondroma in the finger: A case report and review of the literature. *Ann. Acad. Med. Singap.* **1999**, *28*, 590–592.
46. Goldberg, G. Supplementary motor area structure and function: Review and hypotheses. *Behav. Brain Sci.* **1985**, *8*, 567–588. [CrossRef]
47. Nisbett, R.E.; Wilson, T.D. Telling more than we can know: Verbal reports on mental processes. *Psychol. Rev.* **1977**, *84*, 231. [CrossRef]

48. Bagozzi, R.P. The role of psychophysiology in consumer research. In *Handbook of Consumer Behavior*; Robertson, T.S., Kassarjian, H.H., Eds.; Prentice-Hall: Hoboken, NJ, USA, 1991; pp. 124–161.
49. Wang, Y.J.; Minor, M.S. Validity, reliability, and applicability of psychophysiological techniques in marketing research. *Psychol. Mark.* **2008**, *25*, 197–232. [CrossRef]
50. Parsons, T.; Duffield, T. Paradigm Shift Toward Digital Neuropsychology and High-Dimensional Neuropsychological Assessments. *J. Med. Internet Res.* **2020**, *22*, e23777. [CrossRef]
51. Kuipers, B. The "map in the head" metaphor. *Environ. Behav.* **1982**, *14*, 202–220. [CrossRef]
52. Passini, R. Spatial representations, a wayfinding perspective. *J. Environ. Psychol.* **1984**, *4*, 153–164. [CrossRef]
53. Hund, A.M.; Minarik, J.L. Getting from here to there: Spatial anxiety, wayfinding strategies, direction type, and wayfinding efficiency. *Spat. Cogn. Comput.* **2006**, *6*, 179–201. [CrossRef]
54. Lyons, I.M.; Ramirez, G.; Maloney, E.A.; Rendina, D.N.; Levine, S.C.; Beilock, S.L. Spatial Anxiety: A novel questionnaire with subscales for measuring three aspects of spatial anxiety. *J. Numer. Cogn.* **2018**, *4*, 526–553. [CrossRef]
55. Vidler, A. Warped space: Architectural anxiety in digital culture. In *Impossible Presence: Surface and Screen in the Photogenic Era*; University of Chicago Press: Chicago, IL, USA, 2001; pp. 285–303.
56. Kobes, M.; Oberijé, N.; Groenewegen, T.M.; Morsche, T. *Serious Gaming for Behavioural Assessment and Research in Case of Emergency. An Evaluation of Experiments in Virtual Reality*; Paper Presented at the SimTecT 2009 Simulation Conference and Exhibition; Citeseer: Adelaide, Australia, 2009.
57. Kobes, M.; Helsloot, I.; De Vries, B.; Post, J.G. Building safety and human behaviour in fire: A literature review. *Fire Saf. J.* **2010**, *45*, 1–11. [CrossRef]
58. Golden, C.J. *Diagnosis and Rehabilitation in Clinical Neuropsychology*; Thomas: Springfield, QLD, Australia, 1978.
59. Horton, A.M., Jr. Behavioral neuropsychology in the schools. *Sch. Psychol. Rev.* **1981**, *10*, 367–372. [CrossRef]
60. Ye, G.; Chen, L.; Feng, X.; Yang, J.; Yue, H. Study on inducing mechanism of construction workers' risk-taking behavior by noise. *China Saf. Sci. J.* **2020**, *30*, 16–23. (In Chinese) [CrossRef]
61. Huang, X.; Li, W.; Yan, S. Research on pattern of eye-tracking behavior based on tourism map. *Tour. Trib.* **2018**, *33*, 87–96. (In Chinese)
62. Li, J.; Li, H.; Umer, W.; Wang, H.; Xing, X.; Zhao, S.; Hou, J. Identification and classification of construction equipment operators' mental fatigue using wearable eye-tracking technology. *Autom. Constr.* **2020**, *109*, 103000. [CrossRef]
63. Yan, L.; Deng, J.; Yan, M.; Zhang, X. The experimental investigation method on engineering projects management: Based on the experiment of contractor performance behavior as an example. *J. Eng. Manag.* **2016**, *30*, 87–92. (In Chinese) [CrossRef]
64. Duschek, S.; Schandry, R. Functional transcranial Doppler sonography as a tool in psychophysiological research. *Psychophysiology* **2003**, *40*, 436–454. [CrossRef]
65. Mehta, R.K.; Parasuraman, R. Neuroergonomics: A review of applications to physical and cognitive work. *Front. Hum. Neurosci.* **2013**, *7*, 889. [CrossRef] [PubMed]
66. Pizzagalli, D.A. *Electroencephalography and High-Density Electrophysiological Source Localization*; Cambridge University Press: Cambridge, UK, 2007; pp. 56–84.
67. Nozawa, T.; Kondo, T. *A Comparison of Artifact Reduction Methods for Real-Time Analysis of fNIRS Data*; Paper Presented at the Symposium on Human Interface; Springer: Berlin/Heidelberg, Germany, 2009.
68. Zama, T.; Shimada, S. Simultaneous measurement of electroencephalography and near-infrared spectroscopy during voluntary motor preparation. *Sci. Rep.* **2015**, *5*, 1–9. [CrossRef] [PubMed]
69. Jolly, E.; Chang, L.J. The flatland fallacy: Moving beyond low-dimensional thinking. *Top. Cogn. Sci.* **2019**, *11*, 433–454. [CrossRef] [PubMed]
70. Lucko, G.; Rojas, E.M. Research validation: Challenges and opportunities in the construction domain. *J. Constr. Eng. Manag.* **2010**, *136*, 127–135. [CrossRef]
71. Li, Z.; Meng, Q.; Sheng, Z.; Li, Q. Analysis on performance and evolution of mass stimulation under project quality optimization. *Chin. J. Manag. Sci.* **2012**, *3*, 112–121. (In Chinese) [CrossRef]
72. Bernold, L.E.; Lee, T.S. Experimental research in construction. *J. Constr. Eng. Manag.* **2010**, *136*, 26–35. [CrossRef]
73. Zhou, X.; Hu, Y.; Liao, P.; Zhang, D. Hazard differentiation embedded in the brain: A near-infrared spectroscopy-based study. *Autom. Constr.* **2021**, *122*, 103473. [CrossRef]