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MEASURING THE “INVISIBLE”: CLARIFYING THE CONCEPT OF COGNITIVE EFFORT IN TRANSLATION AND INTERPRETING PROCESSES¹

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Abstract

Although translation and interpreting (T&I) involve multiple cognitive processes, the role of cognitive effort is often overlooked and needs to be conceptualized more fully to better understand the complexity of these tasks. This article seeks to “measure the invisible” by 1) exploring its definition and application in existing research, 2) conducting a multidimensional analysis based on cost and reward, and 3) highlighting its relevance to T&I research and education. Our framework includes internal cost, opportunity cost, need for

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cognition, and learned industriousness. This allows for a more precise measurement of effort and a better understanding of individual differences and task requirements in T&I research. For education, the framework offers insights into strategies for managing workload, distributing practice, and developing adaptive expertise. By clarifying the multidimensional nature of cognitive effort, we can improve T&I research and develop sustainable practices for practitioners.

Keywords: cognitive effort, translation and interpreting (T&I), internal cost, opportunity cost, need for cognition, learned industriousness

1. INTRODUCTION

Many exceptional human skills, such as reading, mastering a musical instrument, and writing complex software, including translation and interpreting, require thousands of hours of practice and continuous cognitive effort. Cognitive effort is the most difficult to understand but studying this type of effort is “key to gaining insights into the translation process” (Lacruz, 2017, p. 387). Time pressure has increasingly become a common feature of translation and interpreting (T&I). The cross-border intertwining of T&I has led to time pressure playing a greater role in translation activities such as consecutive interpreting, simultaneous interpreting, sight translation, audio-visual translation, and

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translation under time pressure (Zou & Liu, 2020). The common feature of the above-mentioned translation activities under time pressure is that translators have to think and decide in a short time frame, often having to translate word-for-word, chopping off faster, making the trade-off between effort and effect more important. On the one hand, people may voluntarily exert effort in everyday life even if they are not rewarded for it, but popular scientific theory suggests that effort is unpleasant, and people avoid it as much as possible (Kurzban, 2016; Shenhav et al., 2017). On the other hand, some researchers have recently begun to critically question whether cognitive effort is always repulsive (Inzlicht et al., 2018; Székely & Michael, 2021). They argue that demanding cognitive activities can be experienced as rewarding and valuable in certain situations. In other words, cognitive effort acts as both a cost and a reward in cognitive activities including T&I, and its precise role remains unclear. More research is needed to clarify the concept and characteristics of cognitive effort in this context.

This study aims to clarify the concept and characteristics of cognitive effort in T&I by analysing its definition, operationalization, and multidimensional nature. A multidimensional

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framework is proposed that includes factors such as internal cost, opportunity cost, need for cognition, and learned industriousness. Implications for translation research, training and sustainable practices are also discussed. This study aims to make cognitive effort a “visible” and theoretically grounded construct in T&I that underpins future research and pedagogy.

2. COGNITIVE EFFORT AND ITS RESEARCH IN T&I

2.1. Effort and Cognitive Effort

An effort is a purposeful physical or mental activity, an explicit behavior that can be observed by oneself and others (de Morree & Marcora, 2010, p. 377). Effort is the mediator between a person’s potential performance on a task and the performance he or she produces. Effortful actions can be considered the opposite of automatic actions. Cognitive effort is defined as “the engaged proportion of limited-capacity central processing” (Tyler et al., 1979, p. 607). Cognitive effort is the mental or physical exertion required to complete a task. It is often measured in terms of the attention or concentration required. Cognitive effort can be influenced by many factors, including the difficulty of the task, the

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person’s motivation, and level of knowledge. There is a complex interaction between cognitive effort and task load, task performance, cognitive needs, motivation to learn, cognitive competence and other factors that together play an important role in a person’s performance and competence development on complex tasks. This has become the focus of research in psychology, cognitive science, neuroscience, and other fields.

2.2. Research on Cognitive Effort in T&I

Cognitive research on T&I processes began in the 1960s and 1970s and continued into the 1980s. Early researchers discussed cognitive resources (Gerver, 1969) and cognitive load (Kirchhoff, 1976) in the process of interpreting. Later, Gutt (1991/2000) introduced the concept of cognitive processing effort into translation theory through Sperber and Wilson’s (1986) relevance theory. Gile (1995/2009) proposed a model of cognitive effort for interpreting that focuses on the cognitive effort and energy interpreters expend and coordinate for each subtask of the interpreting process. This model also describes the cognitive constraints interpreters may encounter during interpreting and provides a cognitive explanation for the phenomenon of interpreters’ poor performance (Su et al., 2021).

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Since the turn of the century, with the continuous development of cognitive research in T&I, the study of cognitive effort has become a crucial aspect of T&I process research, especially concerning the cognitive load of local and global processing. The relationship between effort and effect has been discussed according to the concept of “least effort” and it is becoming increasingly clear that achieving a good balance between minimum effort and maximum effect is an important parameter for measuring the performance and ability of a translator or an interpreter. The analysis of cognitive effort in T&I processes is central to deciphering the balance between effort and effect, and its relationship to performance and beyond. Apart from its complexity, effort is also an ethical issue in T&I processes, as readiness preference (whether to exert effort and how much) and age preference (older people do not like tasks that require cognitive effort, even if they behave the same way as younger people) (Pym, 2015/2020) respond to objective cognitive load. High-risk translation tasks require more effort than low-risk tasks. Research on cognitive effort in T&I processes has provided valuable insights into the complex cognitive processes involved in these tasks. However, there are still some unanswered questions that need to be addressed in future research.

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Firstly, the definition remains unclear, and the understanding of its characteristics is simplified and vague. Cognitive effort is a complex concept that has been defined in different ways. Some definitions focus on the mental resources required to perform a task (Shenhav et al., 2017), others on the subjective perception of effort (Massin, 2017), and still others on the dynamic nature of cognitive effort, which may vary at different stages of task performance (Székely & Michael, 2021; Carruthers & Williams, 2022; Gado et al., 2023). There is no universally accepted definition of cognitive effort. In the T&I process, cognitive effort is usually considered as an adjunct to task difficulty, cognitive load, and translator/interpreter performance. This means that cognitive effort is often measured as a substitute for these other variables. Time factors in task completion as an indicator of cognitive effort may ignore the fact that task difficulty, cognitive load and translator/interpreter competence can influence cognitive effort (Zhou et al., 2021). Subjective measurement tools such as questionnaires or scales have “significant limitations” (Wals & Wichary, 2022). Overall, there is no universally accepted definition of cognitive effort and no unproblematic method for measuring it. This poses a challenge to the control of variables and the validity of the corresponding studies.

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Secondly, the factors that influence cognitive effort and its relationship to performance are inadequately discussed. For example, fatigue, stress, and motivation affect cognitive effort, and the relationships between all these factors affect performance in cognitive activities, making it even more difficult to differentiate the role of cognitive effort in this process. The role of individual differences in cognitive effort also varies. Some people naturally have a higher stamina or resilience to stress due to genetic factors. Personality traits can also influence how people respond to stress and fatigue. People with mental health conditions, such as depression or anxiety disorders, might be more susceptible to stress and fatigue. These conditions can also affect cognitive functions, such as attention and memory, thereby influencing cognitive effort. People vary in their inherent cognitive abilities, such as working memory capacity or attention span. Those with higher capacities might be less susceptible to cognitive fatigue and maintain high performance for longer periods. In addition, the characteristics of a task influence the cognitive effort required. The difficulty of the task, the degree of familiarity with the source and target languages, and the purpose of the translation can all influence cognitive effort. Last but not least, the strategies used by translators can also influence cognitive

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effort, as some strategies are more efficient than others. Cognitive effort in complex cognitive activities needs to be considered in the context of the characteristics and properties of the activity itself. However, previous studies of T&I processes have oversimplified this. This is an area that deserves the attention of T&I practitioners and researchers alike.

Third, methods for measuring cognitive effort are limited and are often mixed with methods for measuring related factors such as task difficulty and task load. For example, self-report measures such as questionnaires are often used to measure both cognitive effort and task difficulty, which compromises validity. Rarely is the triangulation method used, i.e., a combination of self-reports, behavioral measures such as reaction times and psycho-physiological measures such as eye tracking or pupillometry and EEG. This significantly limits research design and validity. Translation research is essential for understanding complex cognitive and linguistic processes involved in human language and cognition. The field needs to apply state-of-the-art methods, including computational modelling and neuroimaging, to advance knowledge while contributing to the cognitive study of language. For example, psychophysiological measures such as pupillometry and EEG can provide objective

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measures of the cognitive effort required for T&I tasks. Triangulation of subjective assessments with behavioral and psychophysiological measures is necessary to distinguish cognitive effort from related variables.

Given the complexity of the cognitive effort, it is crucial for promoting T&I performance and learning to view it as both a mental cost and a reward. This perspective requires a multidimensional framework and sensitive measurement tools that capture cognitive effort in all its complexity. A sophisticated understanding of cognitive effort must consider its dual nature as both a taxing mental experience and a driver of benefits such as mastery and productivity. Progress depends on a multidimensional framework that recognizes cognitive effort as an interplay between internal costs, opportunity costs, the need for cognition, and learned industriousness, which are increasingly interwoven with task characteristics.

3. THE COST OF COGNITIVE EFFORT

Effort consumes resources, and individuals tend to avoid effort or to achieve maximum results with minimum effort. This reflects the “effort as a cost” property, which is confirmed and reinforced by current theoretical and empirical research in

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cognitive neuroscience and economics. This tendency is due to both the internal costs of effort and the opportunity costs associated with using resources for cognitive tasks. The internal costs refer to the resources spent on the effort itself, such as time, energy, and attention. Opportunity costs refer to the potential benefits that could have been gained by using these resources elsewhere. By considering both the internal and opportunity costs of the effort, individuals can make more informed decisions about how to allocate their resources more efficiently. Understanding the nature of these costs is important for developing models of decision-making and for designing interventions to promote more efficient use of cognitive resources. In the following sections, we will explore each of these costs in more detail.

3.1. Internal Cost

The internal cost of cognitive effort is reflected in the limited capacity of working memory, which is a recognized determinant of human learning. Early research in this area proposed the “magic number 7”, which states that the span of short-term memory is 7 ± 2 , meaning that people can remember about seven chunks of information in short-term memory tasks (Miller, 1956). However, later research found that

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the magic number should be closer to 4, with the span of short-term memory being 4 ± 1 or between 3-5. This capacity occurs in blocks of three to five in young adults, less so in children and older people (Cowan, 2001). Recent research (Gobet & Clarkson, 2004) suggests that the magic number of 4 is still too optimistic and should be closer to 2. In addition, the size of the chunks stored in short-term memory, rather than the number, seems to affect individual memory. In summary, human cognitive resources are limited and must be used wisely. Cognitive effort is expensive, and humans have been described as “cognitive misers” (Fiske & Taylor, 1984) who exert as much effort as is necessary to make satisfactory decisions. They do not always make the best decisions but take shortcuts whenever possible.

The internal cost of cognitive effort is also reflected in the limited representational resources available to individuals when performing cognitive activities. Individuals have a limited amount of representational information that they can process in a given period (Musslick et al., 2016). This means that individuals must divide, separate, and distribute their representational resources during multitask cognitive activities, which may affect their ability to complete specific cognitive tasks (Musslick & Cohen, 2021). The fuzzy-trace theory proposed by

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Brainerd & Reyna (1990) is widely used in many disciplines, including linguistics. The theory states that the relationship between precision and ambiguity is dialectical and contradictory, and that there is no insurmountable gap between the two. When people make meaning of information, they tend to use vague traces to represent information because they are more accessible and require less cognitive effort. In contrast, precise traces are more likely to be disturbed and then forgotten. Most human cognitive activities rely on vague representations, such as sensations and patterns. Moreover, studies on language comprehension have shown that the syntactic and semantic representations produced by the language comprehension system are only “good enough” for a given task and are not precise and detailed representations of speakers’ utterances (Ferreira et al., 2002; Ferreira & Patson, 2007).

Overall, the limited capacity of working memory impairs human learning and the ability to remember and process information in T&I tasks. The limited representational resources available to individuals affect their ability to perform cognitive tasks, including multitasking in T&I activities that involve, for example, multiple cognitive processes such as comprehension, memory retrieval, decision-making,

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and production. The internal costs of cognitive effort, such as the limited capacity of working memory and representational resources, are important factors in understanding cognitive effort in T&I processes. The internal costs of cognitive effort play an important role in our understanding of cognitive effort in T&I processes.

3.2. Opportunity Cost

When people choose to engage in one task, they often lose the opportunity to engage in other tasks, which means that cognitive effort can manifest as an opportunity cost (Kurzban et al., 2013; Yi et al., 2019). Translators and interpreters have limited mental resources. Thus, when they expend cognitive effort on a task, they forgo the opportunity to use those resources for other purposes. For example, simultaneous interpreters have to listen to a speaker in one language and translate it into another language in real time, which demands a high level of cognitive effort. If an interpreter chooses to focus more on accuracy, they might sacrifice speed or vice versa. This is an example of opportunity cost - the resources spent on improving accuracy cannot be used to increase speed. This trade-off, characterized by opportunity cost, influences how much effort they are willing to expend. The opportunity cost of

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cognitive effort is mainly explained from the perspective of a benefit-cost trade-off, which is rooted in the “principle of least effort”. This principle states that people tend to perform the least labour-intensive behaviour and complete tasks with the least effort required (Zipf, 1949; Case, 2005). Since the principle of least effort was established, it has been studied and combined with language comprehension and information processing. Researchers have pointed out that the principle of least effort is a key concept in understanding the true nature of language behaviour (Martinet, 1960). Heuristics are not simply handicapped versions of optimal strategies; in many real-world settings, there are no optimal strategies at all (Gigerenzer et al., 1999). In translation, finding the best solution for maximum benefit requires translators and interpreters to exert the least effort to achieve the maximum effect (Levy, 1967). As effort increases, the perceived value of further effort may decline due to increasing opportunity costs of that additional effort. Translators and interpreters therefore try to minimize effort.

Studies have shown that both reading and listening comprehension, which are involved in translation comprehension, have the effect of “least effort”. Reading research based on eye-tracking technology

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shows that the reader’s eyes do not read word by word from left to right but fixate only about 60% of the text (Rayner et al., 2011). The brain infers and receives all information based on partial information and impressions, using syntactic and semantic rules. This is also confirmed by the “transposed letter effect”, which states that the random arrangement of letters in the middle of a word has little effect on the text comprehension of skilled readers if the first and last letters of the word are arranged correctly (Rawlinson, 2007). Similarly, the study found that listening comprehension of a spoken sentence is not always based on a comprehensive analysis of the words and syntax of the utterance. Instead, listeners may perform a superficial analysis by picking out a few words and using presumed plausibility to arrive at an understanding of the meaning of the sentences (Ayasse et al., 2021). Opportunity costs inform the design of T&I training, firstly by identifying ways to reduce or increase the value of effort, e.g., by providing strategies to minimize memory or problem-solving load, and secondly by tailoring training to individual differences in opportunity costs rather than adopting a “one-size-fits-all” approach.

Overall, opportunity cost is an important aspect of understanding cognitive effort in T&I. As effort

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increases during a T&I task, opportunity costs also increase. Over time, the opportunity cost increases as mental resources are depleted, reducing the willingness to exert effort, and leading to fatigue. Considering the trade-offs posed by opportunity costs provides useful insights into the dynamics of cognitive effort in T&I and how to optimize training. Considering these trade-offs can help maximize the benefits of cognitive effort while minimizing its costs.

4. THE REWARD VIEW OF COGNITIVE EFFORT

Effort is closely related to motivation and value. The more value a task has for a person, the more effort he or she is willing to exert effort. Effort can increase the outcome of the effort and the value of the effort itself, which can even play the role of a reinforcer to motivate effort, reflecting the property of “effort is a reward”. The reward perspective of cognitive effort can be explained from two aspects: the need for cognition and learned industriousness. Some people have intrinsic motivation and enjoyment in cognitive activity. For them, mental effort is inherently rewarding. They have a high need for cognition. Through experience, individuals

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can learn that exerting effort leads to positive results. This shapes attitudes and values that make effort seem worthwhile. In the following sections, we will explore each of these perspectives of cognitive effort as a reward in more detail.

4.1. Need for Cognition

The need for cognition is defined as “the need to understand and make reasonable the experiential world” (Cohen et al., 1955, p. 291), “the tendency of individuals to engage in and enjoy thinking” (Cacioppo & Petty, 1982, p. 116). Cacioppo and Petty (1982) also developed the Need for Cognition Scale to divide subjects into those with a high need for cognition and those with a low need for cognition, based on the scale scores to examine individual differences in the need for cognition and its effect and role in cognitive activities. Studies have shown that cognitive needs influence individuals’ efforts in information processing. Compared to people with low cognitive needs, people with high cognition need to expend more effort on cognitive activities, perform better in retrieving information, and complete cognitive tasks better (Xu & Zhou, 2010). The exact mechanisms by which the need for cognition influences these

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outcomes are not yet fully understood, but it is thought to be

related to differences in attention, motivation, and information processing. The reasons for individual differences in need for cognition are still unclear, but studies have found that individuals’ learning experiences, tolerance for setbacks, and culturally determined factors may have an impact on individuals’ need for cognition (Cacioppo et al., 1996, p. 215; Inzlicht et al., 2018, p. 342). For example, people from cultures where education and intellectual achievement are highly valued are more likely to have a high need for cognition. The need for cognition exhibits individual differences, and different peoples have different views and perceptions of effort and its rewards. In summary, the need for cognition highlights individual differences in cognitive effort as a reward.

4.2. Learned Industriousness

While the need for cognition highlights static individual differences in the cognitive effort as a reward, learned industriousness shows more dynamic changes and developments in the cognitive effort as a reward. The theory of learned industriousness states that “rewarded effort contributes to durable individual differences in

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industriousness” (Eisenberger, 1992, p. 248). This shows that the perceptions of cognitive effort as

rewarding can change dynamically through experience and learning. On the one hand, people who have experienced effort being rewarded through conditioned learning tend to choose high-effort behaviours (Xu & Zhang, 1996) and then increase the value of high-effort tasks (Yi et al., 2019; Clay et al., 2022). This suggests that people who exert effort are more likely to do so when rewarded and find it more rewarding. However, as working memory has a limited capacity, teaching methods should avoid overloading it with additional activities that do not directly contribute to learning overload, as this will hinder learning progress (Zhong & Sheng, 2017). Instead, well-designed tasks that require moderate cognitive effort can contribute to learned industriousness by providing rewarding experiences of effort and reinforcing perceptions of effort as valuable and rewarding. In summary, learned industriousness shows that people’s propensity to view cognitive effort as rewarding can change through experience. When effort is appropriately rewarded, people become more industrious over time, more willing to exert effort and see greater value in it.

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Both concepts offer insights into optimizing cognitive effort. The need for cognition suggests developing strategies based on stable traits, while

learned industriousness suggests that industriousness can be developed through appropriate reward and reinforcement of effort.

5. IMPLICATIONS FOR T&I RESEARCH

5.1. Cognitive Effort as a Cost

Research on cognitive effort has implications for T&I studies. First, we should be fully aware of “dodging” in cognitive effort. Behavioural research shows that people’s willingness to choose high effort decreases as effort increases, which is called “effort discounting”; if the incentive is low or the difficulty is too high, the individual’s effort will not follow. For example, if you have to study very hard for a good grade, the value of getting that grade goes down. This means that cognitive effort is also likely to reduce or diminish the value of a good grade. This suggests that high cognitive effort can reduce the perceived value or reward of an outcome. As task difficulty increases, the two can be separated (Brehm & Self, 1989; Richter, 2016). In T&I, cognitive effort represents an “optimization” that

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balances effort and effect. The concept of effort discounting can help optimize the design of T&I studies and offer new research questions. For

example, tasks should be designed to gradually increase in difficulty, allowing individuals to adapt and build up their cognitive stamina over time. It is also important to ensure that rewards (e.g., feedback, recognition, grades) are commensurate with the effort invested. Understanding effort discounting can help trainers tailor strategies to individual needs, considering their willingness and ability to exert cognitive effort. Cognitive effort is a goal-directed behaviour that depends on factors such as willingness, ability, and situational demands. It should not be roughly equated or measured with indicators such as task difficulty, cognitive load, or performance alone. Single measures of task difficulty, cognitive load, or performance alone do not adequately capture the complexity of cognitive effort. T&I research should take full account of how cognitive effort interacts with other variables and aim for a multidimensional interpretation of both the research process and the results. Cognitive effort is complex and depends on the incentives, difficulties, and rewards involved in a given situation.

Secondly, based on control variables, we should improve the reliability and validity of the research

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through triangulation. Task difficulty is often used as an operational definition of effort (Wang et al., 2017). The assumption is that the more difficult the

task, the greater the effort that the individual has to exert. However, effort refers to the active cognitive processing required of an individual, while difficulty refers to the characteristics of the task itself (Cao et al., 2022). Gile (2020) also pointed out that it is useful to distinguish between “cognitive load” and “cognitive effort”, the former being the difficulty of the task itself and the latter being the capacity of the task performer (relevant knowledge, skills, tactics, strategies) as reflected in the actual effort invested in the task. In the translation task, subjects indicate anxiety, stress, fatigue, and other feelings when reporting their effort. These accompanying feelings are not conducive to the subjects’ normal cognitive effort. They can be the trigger for “effort discounting”, which needs to be properly considered and addressed in the design and conduct of the research. Misuse of measures of cognitive effort and cognitive load should be avoided. If someone is not motivated, they will exert less effort, even if the task is more difficult (Gile, 2021). In addition to the subjective measures of the Need for Cognition Scale (NFC), objective measures such as Effort Expenditure for Rewards Tasks, Cognitive Effort Discounting Paradigm,

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Motivation for Cognition State Scale, etc. can also be used in research (Treadway et al., 2009; Westbrook et al., 2013; Westbrook & Braver, 2015;

Blaise et al., 2021). Using multiple measures, both subjective and objective contributes to triangulation and improves reliability and validity. Task difficulty alone does not necessarily predict the cognitive effort exerted, as this depends on motivation, capacity, feelings, and other factors. Research should clearly distinguish between cognitive load/task demands and cognitive effort invested by participants.

5.2. Cognitive Effort as a Reward

Firstly, we need to consider individual differences in cognitive effort and incorporate this into research design and interpretation of results. Effort is an active process that requires the participation of the will. Therefore, when researching T&I processes, we need to consider group and individual differences in the cognitive effort of translators and interpreters. Depending on individual differences in cognitive effort and influencing factors such as personal learning experiences, setback tolerance, culturally determined factors, etc., we can look at the cognitive effort of professional translators and

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student translators under different cognitive loads or examine the development of student translators’ cognitive effort at different stages. Translators and interpreters at different levels have different

competencies; the ratio of input effort to output is high for high-level translators, and the reverse is true for low-level translators. As research has found, learners increase this allocation of attentional resources when they encounter valuable information and perform better on tasks (Ariel & Castel, 2014). We can also say that whether cognitive effort can be used more efficiently is part of a translator's competence. There are at least two explanations for the uneven impact of cost accounting in the T&I process. One is that there is insufficient expectation of translation performance, which includes evaluation of translation (self-assessment + assessment by others); the second is that the allocation of cognitive resources in the T&I process is not effective enough. The use of effort is a skill that is also gradually developed and improved. Various human activities can be performed with minimal effort for maximum effect, but the duration of the necessary training process varies from person to person.

Secondly, we need to pay attention to the changes and development of individual cognitive effort and

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examine its synergistic changes and development with cognitive and translational competence. Cognitive training in the past has not had an all-encompassing effect on improving cognitive skills.

Relevant cognitive training such as “learned industriousness” could be a breakthrough in improving the learning effect. By designing cognitive training tasks that have an “optimized” cognitive load, mobilizing cognitive effort that conforms to the general rules of skill acquisition and individual development, and maximizing the added value of cognitive effort, we can expect individual learning ability and learning effect to improve through sustained cognitive effort. In this process, multiple or repeated measures of cognitive effort should be made on long-term tasks. In this way, the changes and evolution of cognitive effort can be effectively tracked and the role of cognitive effort in representing the complex interactive relationship between cognitive load and task performance can be further investigated. The assumption that people want to take the path of least resistance may not be an inherent feature of human motivation. The tendency to avoid challenging tasks may be the result of a person’s learning history, depending on the reward pattern; people may intrinsically value and seek effort (Clay et al., 2022). The positive effects of an environment that values effort and

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individual growth on the evaluation of effort and willingness to mobilise effort and tackle challenging tasks are all important. So, there is still the question of whether it is primarily performance or effort that

is rewarded. This makes all the questions around the whole process complex and deserves to be explored further.

6. CONCLUSION

In summary, cognitive effort is a crucial but under-researched aspect of translation and interpreting (T&I) processes. It is a multi-faceted construct that encompasses not only the mental resources required for T&I tasks but also the subjective perception of effort. This effort is influenced by a variety of factors, including task characteristics, individual differences, motivation, stress, and the strategies used by translators and interpreters. Understanding cognitive effort in T&I processes requires a comprehensive and multidimensional approach that considers both the taxing nature and the potential benefits.

Future research should aim to further clarify the concept and characteristics of cognitive effort in T&I processes. This includes developing more accurate measures of cognitive effort and a deeper

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understanding of how it relates to individual differences and task demands. Such research could provide valuable insights for both T&I research and practice, including strategies for managing

workload, distributing practice, and developing adaptive expertise. Ultimately, a more nuanced understanding of cognitive effort could lead to more sustainable practices for practitioners in the field of translation and interpreting.

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Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/ctl20238>

REFERENCES

Ariel, R., & Castel, A. (2014). Eyes wide open: Enhanced pupil dilation when selectively studying important information. *Experimental Brain Research*, 232(1), 337-344. <https://doi.org/10.1007/s00221-013-3744-5>

Ayasse, N. D., Hodson, A. J., & Wingfield, A. (2021). The principle of least effort and comprehension of spoken sentences by younger and older adults. *Frontiers in Psychology*, 12, 629464. <https://doi.org/10.3389/fpsyg.2021.629464>

Blaise, M., Marksteiner, T., Krispenz, A., & Bertrams, A. (2021). Measuring motivation for cognitive effort as state. *Frontiers in Psychology*, 12, 785094. <https://doi.org/10.3389/fpsyg.2021.785094>

Brainerd, C. J., & Reyna, V. F. (1990). Gist is the grist: Fuzzy-trace theory and the new intuitionism. *Developmental Review* (10), 3-47. [https://doi.org/10.1016/0273-2297\(90\)90003-M](https://doi.org/10.1016/0273-2297(90)90003-M)

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/cttl20238>

Brehm, J. W., & Self, E. A. (1989). The intensity of motivation. *Annual Review of Psychology*, 40, 109-131.

<https://doi.org/10.1146/annurev.ps.40.020189.000545>

Cacioppo, J. T., Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology*, 42(1), 116-131. <https://doi.org/10.1037/0022-3514.42.1.116>

Cacioppo, J. T., Petty, R. E., Feinstein, J. A., & Jarvis, W. B. G. (1996). Dispositional differences in cognitive motivation: The life and times of individuals varying in need for cognition. *Psychological Bulletin*, 119(2), 197-253. <https://doi.org/10.1037/0033-2909.119.2.197>

Cao, S., Tang, C., Wu, H., & Liu, X. (2022). Value analysis determines when and how to strive. *Advances in Psychological Science*, 30(4), 877-887.

<https://doi.org/10.3724/SP.J.1042.2022.00877>

[7](#)

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/ctl20238>

Carruthers, P., & Williams, D. M. (2022). Model-free metacognition. *Cognition*, 225, 105117. <https://doi.org/10.1016/j.cognition.2022.105117>

Case, D. O. (2005). Principle of least effort. In K. E. Fisher, S. Erdelez, & L. McKechnie (Eds.), *Theories of information behavior* (pp. 289-292). Information Today. <https://api.semanticscholar.org/CorpusID:2913048>

Clay, G., Mlynski, C., Korb, F. M., & Job, V. (2022). Rewarding cognitive effort increases the intrinsic value of mental labor. *Psychological and Cognitive Sciences*, 119(5), e2111785119. <https://doi.org/10.1073/pnas.2111785119>

Cohen, A. R., Stotland, E., & Wolfe, D. M. (1955). An experimental investigation of need for cognition. *The Journal of Abnormal and Social Psychology*, 51(2), 291-294. <https://doi.org/10.1037/h0042761>

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/cttl20238>

storage capacity. *Behavioral and Brain Sciences*, 24(1), 87-114. <https://doi.org/10.1017/S0140525X01003922>

de Morree, H. M., & Marcora, S. M. (2010). The face of effort: Frowning muscle activity reflects effort during a physical task. *Biological Psychology*, 85(3), 377-382. <https://doi.org/10.1016/j.biopsycho.2010.08.009>

Eisenberger, R. (1992). Learned industriousness. *Psychological Review*, 99(2), 248-267. <https://doi.org/10.1037/0033-295x.99.2.248>

Ferreira, F., Bailey, K. G. D., & Ferraro, V. (2002). Good-enough representations in language comprehension. *Current Directions in Psychological Science*, 11(1), 11-15. <http://www.jstor.org/stable/20182754>

Ferreira, F., & Patson, N. D. (2007). The ‘good-enough’ approach to language comprehension. *Language and Linguistics Compass*, 1(1-2), 71-83. <https://doi.org/10.1111/j.1749-818X.2007.00007.x>

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/ctl20238>

Fiske, S. T., & Taylor, S. E. (1984). *Social cognition*. McGraw-Hill.

Gado, S., Lingelbach, K., Wirzberger, M., & Vukelić, M. (2023). Decoding mental effort in a quasi-realistic scenario: A feasibility study on multimodal data fusion and classification. *Sensors*, 23(14), 6546. <https://doi.org/10.3390/s23146546>

Gerver, D. (1969). The effects of source language presentation rates on the performance of simultaneous conference interpreting. In E. Foulke (Eds.), *Proceedings of the second Louisville Conference on Rate and/or Frequency-controlled Speech* (pp. 162-184). Center for Rate-controlled Recordings, University of Louisville. <https://eric.ed.gov/?id=ED061682>

Gigerenzer, G., Todd, P. M., & the ABC Group. (1999). *Simple heuristics that make us smart*. Oxford University Press.

Gile, D. (1995/2009). *Basic concepts and models for interpreter and translator training*. John Benjamins Publishing Company. <https://doi.org/10.1075/btl.8>

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/ctl20238>

Gile, D. (2020). *PowerPoint presentation: Research into interpreting (and translation):*

Terminological distinctions that matter. Xi’an Jiaotong University presentation.

Gile, D. (2021). *Cognitive load and effort in translation and interpreting: Methodological issues.* Lecture at CRITT@kent Translation Colloquium.

Gobet, F., & G. Clarkson. (2004). Chunks in expert memory: Evidence for the magical number four...or is it two? *Memory*, 12(6), 732-747. <https://doi.org/10.1080/09658210344000530>

Gutt, E. (1991/2000). *Translation and relevance: Cognition and context.* St. Jerome. <https://doi.org/10.4324/9781315760018>

Inzlicht, M., Shenhav, A., & Olivola, C. Y. (2018). The effort paradox: Effort is both costly and valued. *Trends in Cognitive Sciences*, 22(4), 337-349. <https://doi.org/10.1016/j.tics.2018.01.007>

Kirchhoff, H. (1976). Das Simultandolmetschen: Interdependenz der Variablen im

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/cttl20238>

Dolmetschprozess, Dolmetschmodelle und Dolmetschstrategien (Simultaneous interpreting: Interdependence of variables in the interpreting process, interpreting models and interpreting strategies). In H. W. Drescher, & S. Scheffzek (Eds.), *Theorie und Praxis des Übersetzens und Dolmetschen (Theory and practice of translation and interpreting)* (pp. 59-71). Peter Lang.

Kurzban R. (2016). The sense of effort. *Current Opinion in Psychology*, (7), 67-70. <https://doi.org/10.1016/j.copsyc.2015.08.003>

Kurzban, R., Duckworth, A., Kable, J. W., & Myers, J. (2013). An opportunity cost model of subjective effort and task performance. *Behavioral and Brain Sciences*, 36(6), 661-679. <https://doi.org/10.1017/S0140525X12003196>

Lacruz, I. (2017). Cognitive effort in translation, editing, and post-editing. In J. W. Schiwieter, & A. Ferreira (Eds.), *The handbook of translation and cognition* (pp. 386-401). Wiley-Blackwell. <https://doi.org/10.1002/9781119241485.ch21>

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/ctl20238>

Levy, J. (1967). Translation as a decision process. In *To honor Roman Jakobson: Essays on the occasion of his seventieth birthday, 11, October 1966*, vol. 2 (pp. 1171-1182). De Gruyter Mouton. <https://archive.org/details/tohonorromanjakobson0001unse>

Martinet, A. (1960). *Elements of general linguistics*. Faber and Faber.

Massin, O. (2017). Towards a definition of efforts. *Motivation Science*, 3(3), 230-259. <https://doi.org/10.1037/mot0000066>

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 101(2), 343-352. <https://doi.org/10.1037/0033-295x.101.2.343>

Musslick, S., Dey, B., Ozeimder, K., Patwary, M. M. A., Willke, T., & Cohen, J. D. (2016). Parallel processing capability versus efficiency of representation in neural networks. *Conference: 15th Neural Computation and Psychology Workshop*, Drexel University, Philadelphia, PA.

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/ctl20238>

<https://doi.org/10.13140/RG.2.2.30076.54407>

Musslick, S. & Cohen, J. D. (2021). Rationalizing constraints on the capacity for cognitive control. *Trends in Cognitive Science*, 25(9), 757-775.

<https://doi.org/10.1016/j.tics.2021.06.001>

Pym, A. (2015). Translating as risk management. *Journal of Pragmatics*, 85, 67-80.

<https://doi.org/10.1016/j.pragma.2015.06.010>

Pym, A. (2020). Translation, risk management and cognition. In F. Alves, & A.L. Jakobsen (Eds.), *The Routledge handbook of translation and cognition* (pp. 445-458). Taylor & Francis Group.

<https://doi.org/10.4324/9781315178127>

Rawlinson, G. E. (2007). The significance of letter position in word recognition. *IEEE Aerospace and Electronic Systems Magazine*, 22(1), 26-27.

<https://doi.org/10.1109/MAES.2007.327521>

Rayner, K., T. J. Slattery & D. Drieghe. (2011). Eye movements and word skipping during reading:

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/ctl20238>

Effects of word length and predictability. *Journal of Experimental Psychology: Human Perception and Performance*, 37(2), 514-528. <https://doi.org/10.1037/a0020990>

Richter, M, Gendolla, G. H. E., & Wright, R. A. (2016). Three decades of research on motivational intensity theory: What we have learned about effort and what we still don't know. In A. J. Elliot (Ed.), *Advances in motivation science* (pp. 149-186). Elsevier Inc. <https://doi.org/10.1016/bs.adms.2016.02.001>

Shenhav, A., Musslick, S., Lieder, F., Kool, W., Griffiths, T. L., Cohen, J. D., & Botvinick, M. M. (2017). Toward a rational and mechanistic account of mental effort. *Annual Review of Neuroscience*, 40, 99-124. <https://doi.org/10.1146/annurev-neuro-072116-031526>

Sperber, D., & Wilson, D. (1986/1995). *Relevance: Communication and cognition*. Blackwell.

Székely, M., & Michael, J. (2021). The sense of effort: A cost-benefit theory of the phenomenology of mental effort. *Review of*

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/ctl20238>

Philosophy and Psychology, 12, 889-904.
<https://doi.org/10.1007/s13164-020-00512-7>

Su, W., Li, D., & Cao, H. (2021). 论口译认知负荷的眼动研究 (Eye-tracking studies of cognitive load in interpreting processes). 《外语学刊》 (*Foreign Language Research*), (3), 109-114. <https://10.16263/j.cnki.23-1071/h.2021.03.018>

Treadway, M. T., Buckholtz, J. W., Schwartzman, A. N., Lambert, W. E., & Zald, D. H. (2009). Worth the “EFFfRT”? The effort expenditure for rewards task as an objective measure of motivation and anhedonia. *PLoS One*, 4(8), e6598.
<https://doi.org/10.1371/journal.pone.0006598>

Tyler, S. W., Hertel, P. T., McCallum, M. C., & Ellis, H. C. (1979). Cognitive effort and memory. *Journal of Experimental Psychology: Human Learning and Memory*, 5(6), 607-617.
<https://doi.org/10.1037/0278-7393.5.6.607>

Wals, S. F., & Wichary, S. (2022). Under pressure: Cognitive effort during website-based task performance is associated with pupil size, visual exploration, and users’ intention to

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/ctl20238>

recommend. *International Journal of Human-Computer Interaction*.
<https://doi.org/10.1080/10447318.2022.2098576>

Wang, L., Zheng, J., & Meng, L. (2017). Effort provides its own reward: Endeavors reinforce subjective expectation and evaluation of task performance. *Experimental Brain Research*, 235, 1107-1118.
<https://doi.org/10.1007/s00221-017-4873-z>

Westbrook, A., & Braver, T. S. (2015). Cognitive effort: A neuroeconomic approach. *Cognitive, Affective, & Behavioral Neuroscience*, 15, 395-415. <https://doi.org/10.3758/s13415-015-0334-y>

Westbrook, A., Kester, D., & Braver, T. S. (2013). What is the subjective cost of cognitive effort? Load, trait, and aging effects revealed by economic preference. *PloS One*, 8(7), e68210. <https://doi.org/10.1371/journal.pone.0068210>

Xu, G., & Zhang, Q. (1996). 习得性勤奋的实验研究和理论假 (Experimental research and theoretical hypotheses of learned industriousness). 《心理科学》 (*Journal of*

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/ctl20238>

Psychological Science), (3), 187-189.
<https://10.16719/j.cnki.1671-6981.1996.03.015>

Xu, H., & Zhou, N. (2010). 认知需求对个体信息加工倾向性的影响 (The effects of need for cognition on the dispositional differences of individuals' information processing). 《心理科学进展》 (*Advances in Psychological Science*), 18(4), 685-690.

Yi, W., Mei, S., & Zheng, Y. (2019). 努力：成本还是奖赏? (Effort: Cost or reward?). 《心理科学进展》 (*Advances in Psychological Science*), 27(8), 1439-1450.

Zhong, L., & Sheng, Q. (2017). 如何调控认知负荷“最优化”：发展综合认知能 — 访谈国际著名认知科学家弗莱德·帕斯 (How to ‘optimize’ the cognitive load: Developing complex cognitive skills: An interview with the international famous cognitive expert Fred Paas). 《现代远程教育研究》 (*Research on Modern Distance Education*), 4, 3-10.

Zhou, H., Weng, Y., & Zheng, B. (2021). Temporal eye-voice span as a dynamic indicator for cognitive effort during speech processing: A

Zou D., & Zhang J. (2023). Measuring the “invisible”: Clarifying the concept of cognitive effort in translation and interpreting processes. *Current Trends in Translation Teaching and Learning E*, 10, 217 – 258. <https://doi.org/10.51287/cttl20238>

comparative study of reading aloud and sight translation. In R. Muñoz Martín, S. Sun, & D. Li (Eds.), *Advances in cognitive translation studies* (pp. 161-179). Springer.

Zipf, G. K. (1949). *Human behavior and the principle of least effort: An introduction to human ecology*. Addison-Wesley. <https://archive.org/details/in.ernet.dli.2015.90211/page/n7/mode/2up>

Zou, D., & Liu, Z. (2020). 跨界融合视角下的口笔译再思考 (Rethinking translation and interpreting from the perspective of cross-border integration). 《外文研究》 (*Foreign Language Studies*), (4), 68-74+106.