Toward Understanding the Relationship between Task Complexity and Task Performance

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Abstract. Task complexity has been recognized as one of the most important determinants of human behavior and task performance. This paper reviews the relationship between task complexity and task performance. Influencing mechanism of task complexity is tentatively explored. Then, a conceptual framework is proposed to present the possible relationships among task complexity, task difficulty, self-efficacy, task characteristics, task performer characteristics, and task performance, for the sake of sharing and generalizing scientific findings across different areas.

1 Introduction

Tasks are activities that people should conduct to move their life and work on. As Hackman (1969) argued, "[t]asks play an important role in much research on human behavior, and differences in tasks and task characteristics have been shown to mediate differences in individual and social behavior." [1, Abstract]. One of task characteristics, task complexity, has appeared in numerous studies. Although we could use various tools and techniques, such as automatic machines and computers, to support us in performing tasks, it is undeniable that some our tasks are becoming more and more complex, especially those performed in safety-critical systems. Confronted by more and more reliable tools and techniques, the limitation of human being has been increasingly exposed.

Usually, complex tasks are ill-structured, ambiguous, dynamic, and difficult to be performed. Compared to low-complexity tasks, high-complexity tasks require greater demands on skills, knowledge, cognitive abilities, memory capacities, and task efforts. The complexity of practical problems of decision tasks would prevent people from integrating options, even if they purport to do so [2]. So, to gain a satisfying task performance, we must consider the relationship between task complexity and task performance. On the one hand, it would help us determine whether or not a specific task have an expected performance. On the other hand, it might be possible to predict the direction and magnitude of task complexity effect under the combination of specific tasks and individual differences. In practice, it would improve our ability of staff distribution and effective intervention.

Task complexity has been investigated in fields of goal-setting, decision-making, auditing, learning, human-computer interaction (HCI), and information seeking, retrieval, and searching, etc. Research on task complexity has been reviewed by

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several researchers [3,4]. They primarily focused on the constructs of task complexity. No review on the complexity-performance relationship was found in the literature. This study attempts to fill the gap and to give a better understanding of the relationship.

This paper proceeds as follows. The constructs of task complexity and the differences of several concepts (objective vs. subjective task complexity, task complexity vs. difficulty) are discussed. Four types of the relationship studied in the literature are summarized. Influencing mechanisms of task complexity are tentatively explored. A conceptual framework is proposed to present the relationships among task complexity, difficulty, self-efficacy, task characteristics, task performer characteristics, and task performance and human behavior.

2 Task Complexity

Task complexity has been defined in various ways. However, little consensus existed among researchers who were concerning the properties that make a task complex [3]. Different researchers and studies had a great variation and confounding about the way to understand and to operationalize task complexity [5,6]. As a result of this epistemological problem of task complexity, it is difficult to integrate the findings of task complexity from these studies across different areas, or even in the same area.

Several studies summarized various constructs of complexity [3,4,7-10]. Wood (1986) classified task complexity into three types [5]: component, coordinative, and dynamic complexity. Component complexity is defined as a function of the number of distinct acts that need to be executed and the number of distinct information cues that need to be processed. Coordinative complexity is defined as relationships between task inputs (acts and information cues) and task products. Dynamic complexity is due to "changes in the states of the world which have an effect on the relationships between task inputs and products" [5, p. 71]. In information-intensive tasks, component, coordinative, and dynamic complexity would be interpreted as the amount, relationship, and variation of information, respectively. Campbell (1988) considered four characteristics of task complexity in his review [3]: (1) multiple paths, (2) multiple outcomes, (3) conflicting interdependence among paths, (4) uncertain or probabilistic linkages. Bonner (1994) classified elements of task complexity according to three components of general information processing models [11]: input, processing, and output. Each element of task complexity consists of the amount and clarity of information which correspond respectively to task difficulty and task structure. Harvey & Koubek (2000) proposed a model with three classes of task complexity [12]: scope, structurability, and uncertainty. Their model could be viewed as an extension of Wood's (1986) model. In addition, cognitive effort [13], environmental predictability [14], uncertainty [15], inconsistency [16], priori determinability [9], structure [17], and presentation homogeneity [18] were employed to delineate task complexity. It is acknowledged that the quantity, interaction, and variation of task elements contribute to task complexity [19].

Task complexity is viewed from both objective and subjective perspectives [20]. The former considers task complexity to be directly related to task attributes and independent of task doers [3,5,21]. Subjective perspective considers task complexity as a conjunct property of task attributes and task doers. This view has been widely-supported by researchers from information domain [9, 22]. Subjective complexity is also termed as experienced, perceived, or psychological complexity. In related scientific research, the "objective" view is dominant. In this review, task complexity is specified as an objective property of tasks. When this term indicates a subjective concept in other studies, it will be prefixed with "subjective".

Task difficulty is always confused with task complexity. They are considered to be interchangeable [15], or two different things [11]. Task difficulty is also classified into two types: pre-task difficulty and post-task difficulty [43]. Essentially, pre-task difficulty that defined as the perceived likelihood of success is similar to self-efficacy [23]. We define task difficulty as the amount of effort task doers have to exert in performing tasks, which is closes to post-task difficulty in [43]. Thus, task complexity and difficulty is two different concepts in this review.

Measurement of (subjective) task complexity/difficulty is another controversial issue. There are no general quantification methods for task complexity measurement. Wood suggested three general formulas for calculating component, coordinative, and dynamic complexity, and a simplified weighted formula for total task complexity [5]. In reality, these four formulas were rarely used for quantification. Several existing quantification methods were just appropriate for specific task types. Elementary information processes (EIPs) was used to calculate cognitive effort (a proxy for task complexity) in decision tasks [13, 24]. TACOM (TAsk COMplexity), which is based on graph entropy in software complexity measure, was applied to measure the complexity of proceduralized tasks in emergency operating procedures of nuclear power plants [25]. A similar method was used to evaluate operation complexity in Spaceflight [27]. In HCI, there are several methods that can be used to quantify task complexity, such as cognitive complexity theory [28] and structured task analysis methodology [8]. In laboratory settings, tasks were usually dichotomously designed as relatively "simple" or relatively "complex" based on constructs of task complexity. Subjective task complexity and task difficulty were usually assessed by self-report scales.

3 Complexity-Performance Relationships

Compared to low-complexity tasks, high-complexity tasks require higher human information processing, which would challenge short-term memory, working memory, and long-term memory [38]. Thus, task complexity would influence task performance; however, such influence is less consistent [29]. The determination of such influence depends on the measurement and operationalization of task complexity, measurement of task performance, other task characteristics (e.g., presentation, task type), and task doer characteristics (e.g., experience, motivation). This review primarily concerns with performing tasks, partly with learning tasks.

3.1 Four Types of Relationships

The effects of task complexity on task performance have been investigated in various areas, including goal-setting, auditing, HCI, decision making, material learning, etc.

According to the literature, the measurement and manipulation of task complexity have a great deviation. Task complexity was assessed by self-report scales [30, 32], production rules [31], or dichotomously manipulated as relatively simple and relatively complex according to pure experience [11,36] or constructs [34]. Task performance was evaluated by completion time, correction rate, decision accuracy/bias, or by self-report scale. Some of these previous studies have associated task complexity with the task doer factors such as job experience [30], gender [16], age [31], leader behavior [32], skill [11], knowledge and accountability [33], or with non-task doer-related factors such as presentation [26,34], and training method [35], time pressure [36] and time availability [37].

The relationship between task complexity and task performance are summarized as follows:

- Negative. A majority of researchers suggested that task performance was negatively related to task complexity [11,10,26,31,34,37,38]. For example, decision accuracy was better under the low complexity condition [10]. Based on Campbell's complexity model with four basic characteristics [3], Jack & Ward shown that the presence of two basic characteristics in combination prompted a significant decrement in task performance compared to the cases when a single characteristic was present [38].
- Positive. Several researchers conceived that there existed a positive relationship between task complexity and task performance [18,29,36,39]. The "positive" view in learning tasks is pervasive [39]. Task doers with expert system acquired more procedural knowledge in complex tasks than those in simple tasks [39]. In team tasks, "an increase in task complexity does have a positive motivational effect through maintaining interest in the performance of repetitive operations" [36, p. 37]. Greater task complexity was consistently associated with greater productivity [36]. In job tasks, a high complexity condition would benefit to strategy quality and development [30]. Female auditors showed greater efficiency on the high complex tasks than on the low complex tasks [16].
- Contingent. In this perspective, the complexity-performance relationship is contingent on and moderated by other factors. For example, task performance declined with increasing task complexity only under combinations of low knowledge and high accountability or low accountability and high knowledge; task performance was unaffected by increasing task complexity when auditors had high knowledge and high accountability or have low knowledge and low accountability [33].
- Inverted-U shape. Notwithstanding lacking enough direct evidences of such relationship, a considerable number of researchers believed its existence [3,5,40]. Driver & Streufert demonstrated several evidences when task complexity was operated as the number of input stimuli [44]. Wood argued that the relationship would possibly have a curvilinear form: increasing levels of complexity might initially lead to higher levels of challenge and activation level and have a positive effect on performance; at a much high level of complexity, however, it might lead to lowered performance, because task demands exceed task doers' capacities [5]. In Bonner's study [11], if we just reconsider the relationship between objective task complexity and task performance in ratio analysis tasks, a significant quadratic

relationship was found ($F(2, 8)=3.20$, $p<0.1$), but not a linear negatively relationship ($F(1,9)=1.43$, $p>0.1$). However, in going-concern evaluation tasks this inverted-U relationship was not significant ($F(2, 5)=8.41$, $p>0.1$). To our best knowledge, the inverted-U relationship is only found between visual (or interface) complexity and performance.

3.2 Influence Mechanism of Task Complexity

As this study summarized, the complexity-performance relationship could be negative, positive, contingent, or even inverted-U shape. So, to gain an explicit understanding of this relationship, the influence mechanism of task complexity should be considered. In most pertinent studies, a high-complexity level had a negative impact on performance. It could be explained by several theories. For example, according to the human information processing model, a complex task is likely to challenge short-term, working memory, long-term memory [38]. In complex tasks the amount of information for processing overruns the capability of human beings, which might lead to the deterioration of human performance.

According to schema theory, for a low-complexity task, task performers would have corresponding schemata in long-term memory to deal with the task; however, for a high-complexity task, task doers would be lack of such corresponding schemata in problem-solving process so that they have to take much time to process and to develop the schemata. However, in complex learning tasks, if they have enough time to process information and to integrate new information with schemata in long-term memory, they would develop new schemata and gain more knowledge acquisition [39].

Activation theory has been used to explain the existence of inverted-U relationship between task complexity and task performance [40]. This theory predicts an inverted-U relationship between activation level and performance. Because activation level is believed to have a monotonically positive relationship with task complexity (operated by the number of stimuli, variation, novelty, etc.), thus, the relationship between task complexity and performance appears to be an inverted-U shape. It is pitiful that a few evidences exist to support the inverted-U relationship between task complexity (except visual complexity) and performance. The existence of *Hawthorne Effect* in laboratory settings may hamper the observation of this relationship.

3.3 A Conceptual Framework

It is difficult to generalize the scientific findings in existing studies. Except the absence of a unified definition and measurement of task complexity, different roles that task complexity plays on performance in existing studies contribute to the difficulty of generalization. Researchers focused on the direct effect of task complexity on performance [38], or the interaction effect of task complexity and other factors on performance [32,34,35], or the effect of task complexity and the moderating effect of other factors [11,34], or the effect of other factors and the moderating effect of task complexity [30,41]. Additionally, the confusion between objective and subjective task complexity also contributes to the difficulty of generalization.

To share and generalize scientific findings from different areas and to understand the mechanism of task complexity effect on performance, a general framework is proposed to present the relationships among task complexity, subjective task complexity, task difficulty, self-efficacy, task characteristics, task performer characteristics, and task performance and human behavior (shown in Fig. 1, the number attached the arrows indicates a path of relationship). Several examples of these relationships have been found in existing studies. Task difficulty can predict task performance and task doer behavior [45]; subjective task complexity and self-efficacy affects task performance [35] [46] (See Arrow 1). Self-Efficacy is believed to be influenced by personality, motivation, and the task [47]; subjective task complexity are determined by task complexity, cognitive ability and task motivation [46] (See Arrow 2, 3, 4). Subjective task complexity mediates the effects of task complexity and cognitive ability on task performance [46] (See Arrow 3→1, 4→1); however, task complexity and cognitive ability affect directly task performance [46] (See Arrow 5, 6). Other characteristics, such as time pressure [36], are believed to influence task complexity and task performance (See Arrow 7,8). To verify these relationships and the mediating effect of task difficulty/subjective task complexity, hierarchical regression analysis [41] or data mining tools [42] could be used.

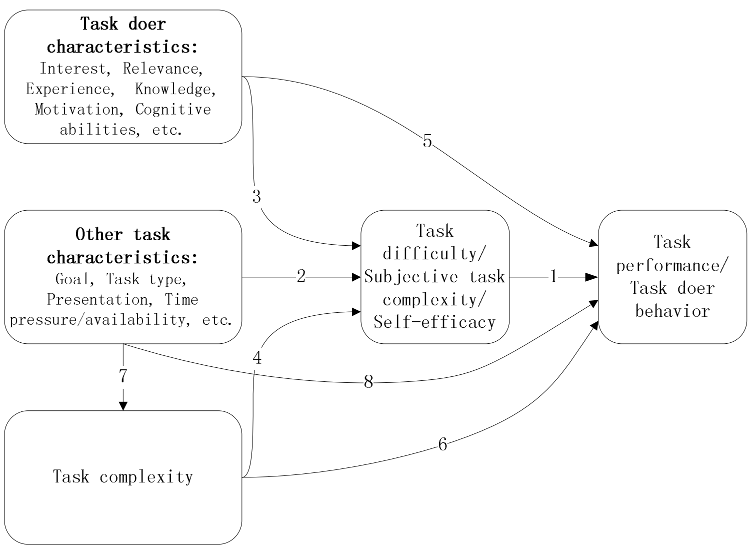

Fig. 1. Conceptual Framework for Studying the Complexity-Performance Relationship

Focusing on the complexity-performance relationship, other factors, such as cognitive abilities, knowledge, and time pressure, could be viewed as moderator factors. It depends on researchers' intentions. This review is interested in the mechanism through which task complexity relates to performance, self-efficacy or task difficulty could be regarded as mediators or moderators. In other research, in which task complexity would be regarded as a moderator, the complexity-performance relationship may not be given. It would be better to provide the complete information so that other researchers could benefit from the shared findings.

4 Conclusion

Accompanying the technological development, specific tasks are becoming more and more complex to be performed and need more cognitive intelligence. For highly reliable systems, the weakness and importance of human beings that confronted by complex tasks have received more attention than ever before. Around the complexity-performance relationship, its type, mechanism, and framework were explored. To minimize the negative effects of task complexity and at the meanwhile to maximize the positive effects of task complexity, future research should go further toward considering the effects of task complexity components on human performance and behavior, the moderating effects of other factors, and the influence mechanism of task complexity.

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