IT Use and the Interruption of NPD Knowledge Work

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Abstract

While product development (NPD) groups typically use information technology (IT) to enhance their knowledge work, such usage also elicits group-level interruptions. This paper develops a conceptual model that studies the partial mediation effect of interruptions on the link between IT use and knowledge integration in NPD. It proposes that IT use causes two interruption types that represent alternate channels of influence on knowledge integration. Specifically, intrusions inhibit knowledge integration by raising group workload, while feedback interventions facilitate knowledge integration by enhancing the group's collective mind. The paper contributes to the literature by providing insights on how IT use affects the knowledge work of groups that are faced with various interruption types.

1. Introduction

A key issue facing cross-functional new product development (NPD) groups has been to effectively leverage their collaborative knowledge work. A key facet of such work is knowledge integration, defined as *access, synthesis, and utilization of complementary, task-related knowledge of NPD group members, to create a collective product solution* [1]. Knowledge integration is especially important in NPD. First, developing new products is a complex process tapping various activities – from idea generation to product commercialization – that hinge on combining multiple sources of expertise [1]. Second, knowledge is inherently fragmented within and across people, and a single individual or functional unit is unlikely to hold all the expertise necessary for effective NPD. Third, prior research has established a positive link between knowledge integration and NPD performance [2].

However, research indicates various challenges to knowledge integration, including lack of interactions and trust among group members [3], succumbing to group consensus [4], as well as events that interrupt the efforts of combining multiple sources of expertise [5]. In particular, whereas information technology (IT) has been increasingly deployed in NPD tasks to facilitate knowledge integration [6], such an undertaking is particularly challenging if the knowledge work of NPD group members is constantly interrupted. Specifically, IT use exhibits both intended and unintended effects on the flow of NPD knowledge work, giving rise to new research areas. First, IT enables knowledge integration by widening the reach for knowledge group members can draw on [7]. Second, while IT is deployed to facilitate knowledge integration, evidence is emerging that it also leads to interrupting knowledge work [8-10]. Third, results for the impact of interruptions are contradictory [10-13]. At the group level (which is the focus of this paper), interruptions have been identified as critical for influencing the group's ability to coordinate its knowledge resources [5, 14, 15]. Yet, IT-related interruptions have also had negative effects on knowledge transfer efforts [14]. Negative effects are typically attributed to two fundamental cognitive activities associated with interruptions: (1) cognitive interference, where the interruptive task produces information cues that draw on the same cognitive resources used for the primary task [16, 17], and (2) capacity interference, where the demands of the interrupt result in exceeding the cognitive capacity of the individual or group [16, 18]. Conversely, positive effects have been credited to the fact that interruptions may give rise to windows of opportunity that allow group members to adjust their focus and better manage the knowledge related to their primary task [5, 19].

In short, IT, interruptions, and knowledge integration seem to be linked in complex ways, and this has not been explicitly addressed in the literature. IT use may enable knowledge integration directly but also indirectly via interruptions. Also, the ensuing effects by interruptions may elicit positive or negative outcomes. This paper aims at better clarifying these links. While most prior studies look at the influence of interruptions on task performance, we believe that such outcomes have been sufficiently examined [10, 15, 17, 20, 21], and we focus on how interruptions mediate the effect of IT use on NPD knowledge integration.

The paper addresses four further research gaps. First, there is a lack of a comprehensive framework that explains the links between IT, interruptions, and knowledge integration. Two theoretical perspectives are relevant, but they explain only part of the picture. Cognitive fit theory [10] proposes that the fit between task demand and IT-based problem representation determines the influence of interruptions. However, the

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theory provides an incomplete picture of interruptions by using IT as a proxy for cognitive capacity and hence ignoring capacity interference. Also, the role of IT is restricted to representing information on a problem for individual decision-making. Hence, it does not readily apply to collaborative IT used in groups. The notion of task-capacity fit, first formulated by Kahneman [16] to explain attention and effort, suggests that the influence of interruptions is determined by the fit between task demand and cognitive capacity of the individual or group [13]. As such, this framework explicitly addresses capacity interference, but not the role of IT.

Second, with few exceptions [5, 10, 14], prior research has overlooked the role of the different types of interruptions [13, 15, 20, 22], even though this can determine the influence of interruptions [5, 23]. This paper proposes that there can concurrently be positive and negative channels of influence for interruptions on knowledge integration depending on interruption type, and that IT can contribute to both of these channels.

Third, most interruptions research involves individuals [10-13, 17, 20, 22] or dyads [8, 15, 21]. Few studies are at the group level [5, 14], and these do not consider the role of IT. Finally, most research is conducted in laboratory settings to test the effects of interruptions on individuals involved in decision-making [5], or problem-solving tasks [10]. There is a dearth of field research that examines how groups conducting knowledge work are interrupted.

Motivated by these gaps, this paper contributes to the literature by unraveling the relationships between IT use, interruptions, and knowledge integration. We ask the following question: *How does IT use affect knowledge integration in NPD groups in a context where their knowledge work is interrupted*? To answer this question, a conceptual model is developed, where the influence of interruptions is determined not by task and technology [10], or by task and cognitive capacity [13], but rather by the cumulative effects of IT, task demand, and collective cognitive capacity. We propose that different interruption types exhibit distinct effects on knowledge integration, and that IT can be a driving force behind instigating these interruptive effects. The next section provides the theoretical background and introduces the proposed framework. Then, a conceptual model is developed with propositions that link the underlying constructs. A discussion of implications and limitations concludes the paper.

2. Theoretical Background

2.1. IT-based knowledge integration barriers

As mentioned at the outset, IT is typically used to facilitate knowledge integration. However, various factors stand in the way of such undertaking. Drawing on the literatures of knowledge integration [1, 24], barriers to IT-enabled collaboration [4, 25], and online knowledge contributions [26, 27], we note that the dominant theoretical approach for examining impediments to IT-enabled knowledge integration focuses on behavioral and structural issues pertaining to the unwillingness or inability of knowledge workers using IT to collaborate and integrate their knowledge. Specifically, factors such as trust [4, 25], social capital [3], social expectations [26], technical compatibility [4], a common knowledge framework [1], departmental thought worlds [24], and enabling organizational structures [4, 24], have been identified.

However, little is known about how disruptive events influence IT use in collaborative knowledge work. Interruptions provide important yet overlooked channels imposing cognitive constraints that may facilitate or inhibit IT-based knowledge integration. Statistics from prior research confirm the implications of interruptions for knowledge work. For instance, knowledge workers switch tasks every three minutes, on average [28]. A survey of over 1,000 US knowledge workers has estimated the costs of interrupting these workers at $588 billion annually [29].

Interruptions are especially forceful in NPD groups. Such groups are composed of knowledge workers from diverse backgrounds that constantly switch between tasks or engage in multiple tasks concurrently rather than proceed sequentially through the traditional stage-gate approach. To better understand the various effects of interruptions, and in particular the way by which they shape the influence of IT usage on knowledge integration in NPD, the remainder of this section introduces a proposed framework of interruptions.

2.2. Proposed framework of interruptions

Interruptions are defined as *external events that break the continuity of primary tasks* [18]. This definition excludes self-initiated interruptions [11]. Common to all interruptions, is that they produce information cues that call on attentional resources, and that need to be processed by the interrupted individual or group, whether immediately or at a later time [21].

Our proposed framework begins with the notion that the impact of interruptions is determined by task demand and cognitive capacity [13, 16]. Interruptions raise task demands, by causing cognitive interference, and/or capacity interference. The interrupted party may reduce the negative effects of these interruptions by leveraging their capacity of cognitive resources, such as individual effort [13], and attentional focus [12].

Several tenets further delineate the proposed framework. First, drawing on Jett & George [18], we

identify two particularly important interruption types for NPD groups engaged in knowledge work: intrusions and feedback interventions. Intrusions are defined as *external, unexpected events that break the continuity of the group's work*. An additional assumption bounding intrusions is that their contents do not reveal critical information about completing the primary tasks. Intrusions faced by NPD group members can be broadly categorized as work-related, non-work-related, and contextual. Work-related intrusions include information and meeting requests by external agents [21], disseminating information unrelated to the primary task, such as alerts, warnings, announcements, and reminders [21], and changes in task and/or project [14, 21]. Non-work related intrusions include social and accidental exchanges [21]. Contextual intrusions include structural changes in the group [14], changes in tools or technologies [14], disruptive organizational events, and resource availability issues, such as system updates, maintenance, failures, and security [30].

Conversely, feedback interventions are defined as *external events revealing perceived inconsistencies between performance expectations and actual task performance* [18, 31]. We make the following assumptions: (1) they occur during engagement in a primary task, (2) they contain specific information about task-related performance discrepancy, and (3) they identify the discrepancy source without constraining actors' choices for response [31]. Feedback interventions are salient in the NPD process, which includes several gates designed to assess the successful completion of various NPD tasks.

Our framework suggests that interventions can directly enhance the cognitive capacity of NPD workers by structuring collective coordination mechanisms [19], enabling "mindful" acquisition of new knowledge routines [14], and expanding pre-existing cognitive schemas [18]. This positive effect is implicitly supported by organizational information processing theory [32]. A feedback intervention that produces information critical to completing the primary task increases the individual's or group's information processing capacity [18]. Hence, we propose that both channels of influence be considered: increased task demand via intrusions, and increased cognitive capacity via feedback interventions.

This framework extends interruptions research in several ways. First, the literature does not consistently recognize the role of interruption type [10, 20]. Instead, the focus has been on interruption properties such as frequency, duration, timing, complexity, and clusteredness [10, 13, 17]. Such properties have implicitly involved a single interruption type; namely intrusions [10, 13, 17]. Additionally, research on interruption properties has retuned mixed results [13, 14, 17], perhaps due to overlooking the actual role of interruption type. Similarly, studies that have considered other interruption types (e.g., interventions) have not explicitly modeled the role of interruption type [5]. Examining a single interruption type – whether implicitly or explicitly – holds its effects constant, which hinders the detection of important outcome variations. Indeed, some studies attribute such variations to interruption type [11, 22]. However, these studies are few and are mostly at the individual level. At the group level, one study looked at interruption types but only in a post hoc exploratory analysis, and indeed found evidence that different types had different effects on knowledge outcomes [14].

Second, our framework extends the dominantly negative view of interruptions [17, 22], by acknowledging recent studies that indicate positive effects, especially for feedback interventions [5, 14]. Our use of both interruption types is key to capturing both the positive and the negative outcomes.

Third, this framework stresses the importance of recognizing the relation between the interrupt and the primary task. Specifically, prior research has assumed that all interruptions are secondary tasks that directly compete for scarce cognitive resources and divert attention from the primary task, while often impeding task resumption [10, 13]. However, feedback interventions, while entailing an initial attention switch, refocus attention on the primary task [5].

Fourth, a dominant view has considered all interruptions to increase task demands, with cognitive capacity merely mitigating those adverse effects [10, 13, 17]. However, as our model shows, we propose that feedback interventions directly influence cognitive capacity. Finally, by understanding interruptions and their impacts, we can better predict how they shape the influence of IT use on knowledge integration in NPD.

3. Conceptual Model

The conceptual model is shown in Figure 1. IT use is posited to trigger both types of interruptions: intrusions and feedback interventions. Both interruption types consume scarce attentional resources and influence NPD knowledge work. The direction of influence is determined by how attention is allocated by the interruption type to the task. Intrusions usurp attention away from the primary task, leading to increases in task demands, or group workload. Conversely, feedback interventions refocus attention on the primary task and enhance cognitive capacity, or collective mind. Finally, knowledge integration is positively influenced by IT use and collective mind, and negatively influenced by group workload. Hence,

the path to NPD knowledge integration contains a direct enabling effect from IT usage, in addition to two partial mediation effects; an inhibiting effect from intrusions and group workload, and a facilitating effect via feedback interventions and collective mind.

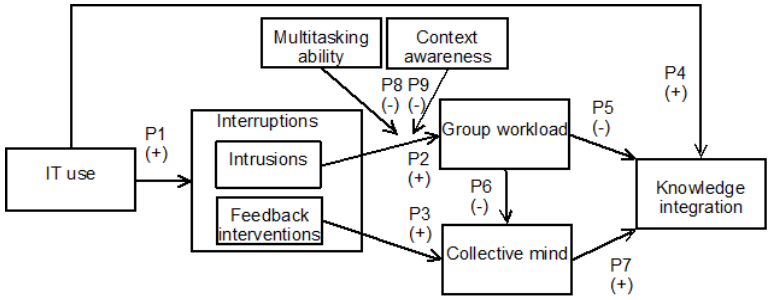

Figure 1. Conceptual model

3.1. IT use and interruptions

Typical usage of IT across the entire NPD domain includes the use of project and process management systems, collaborative systems, and knowledge management systems [6, 33]. First, the NPD group uses tools that manage structural NPD process aspects such as scheduling, assigning tasks, and managing resources. Second, they use collaborative tools such as groupware and workflow. Third, they use tools that create and store knowledge in electronic repositories, tap knowledge directories to locate expertise for given tasks, and engage users in knowledge networks that center on new products and ideas [33].

Whereas these IT tools are designed to facilitate collaborative NPD work, we are especially interested in how their use contributes to interrupting such work. Prior research in human-computer interaction has mostly studied links between IT-induced interruptions and task performance [9, 34], or design aspects that are incorporated into IT (intelligent agents) to mitigate the adverse effects of interruptions [15, 21]. However, evidence of how IT directly leads to interruptions has not been consistently furnished in the literature, beyond anecdotal descriptions [9, 21].

IT use leads to interrupting NPD knowledge work in several ways. First, IT offers a platform for intrusions and feedback interventions. For example, email is a collaboration tool usually configured to instantly alert and intrude on users once a new message arrives. Also, knowledge workers typically react immediately to new email rather than delay response [34]. Hence, as NPD group members continue to use project management, collaborative, and knowledge management tools in their NPD tasks, they face interruptions by the very same tools that facilitate their work. Project management systems entail intrusions in the form of meetings requests, alerts and reminders about meetings, project scheduling, and so forth [21]. Use of collaborative systems may intrude on group members by signaling new message arrivals and when members stop to process the information in the messages. Examples of intrusions from usage of knowledge management systems include interrupting experts in the knowledge directory, and user information requests on online discussion forums. Regarding feedback interventions, Ang et al. [35] found that groups of decision-makers prefer receiving IT-mediated feedback interventions, rather than direct interventions from their managers.

Second, IT usage creates and disseminates information leading to second-order interruptions that may or may not be IT-mediated. Undoubtedly, IT has created an explosion in information content, much of which is enabled by the Internet and advancements in connectivity and storage technologies. For instance, information stored electronically in organizational databases doubles every year [37]. In NPD, IT usage generates information on projects, discussions, and best practices. Indeed, such an effect of IT use on increasing the amount of information stored and disseminated has been found in collaborative groups at a major insurance company [38]. Some of this information is then accessed by external agents (e.g., executives) in pursuit of their daily work. The sheer amount of information makes it difficult to identify and retrieve relevant information, and processing it may entail first-order interruption effects [37]. However, our focus on external interruptions points to the second-order effects, where external agents interrupt NPD group members that created the information and that have the skills to help them make sense of it. This leads to intrusions, such as information and meeting requests. Also, feedback interventions ensue when external agents provide group feedback on information stored in the repositories. Indeed, it was found that the sheer volume of information in electronic databases of collaborative consulting teams prompts users of such

information to request clarifications, meetings, and discuss with information providers various aspects relating to the information [37]. Regarding feedback interventions, information providers are also given feedback regarding the quality and demand of the information stored in the team's database [37]. Nadler [40] suggested that IT use in groups produces information that is used to detect task-related errors, provide feedback, and improve task performance.

Proposition 1a: IT use in NPD is positively associated with intrusions for the NPD group.

Proposition 1b: IT use in NPD is positively associated with feedback interventions for the NPD group.

3.2. Intrusions and group workload

Any task, whether interrupted or not, imposes a mental workload that places demands on attentional resources from the collective pool of attentional capacity [16]. Task demand can be assessed with perceptual measures, such as time pressure, information load, memory loss, and stress [16].

Whereas the literature emphasizes individual task demand [10, 13, 17, 20], we extend this concept to the group-level by drawing on the concept of group workload. Group workload reflects the demands placed on the NPD group by the task environment in relation to the group's finite capacity [42]. It can be assessed using the NASA-TLX index, which measures mental and physical demand, temporal demand, effort, and stress [43]. This scale has previously been used in interruption research to assess individual task demand [22, 44], but it can be extended to the group-level [42]. Similarly, at the group-level, we do not focus on individual intrusions (e.g., a marketing expert popping into the office of a product designer engaged in design activity) but rather, on aggregate effects for the NPD group. Additionally, explicit intrusions at the group-level are included, such as changes in group projects, tasks, and/or roles, IT-related system issues, and other disruptive events [14]. Excluded are planned events, such as group seminars and training sessions.

Intrusions are likely to raise the group's workload, by creating secondary tasks that consume attentional resources and divert from the primary task. First, experimental research on HCI found that intrusions increase time pressures that impede primary task resumption [45], or lead to hasty task resumption to make up for lost work [22]. Second, for mental load, it was found that police radio dispatchers perceived more overload due to intrusions, especially when they had to switch often and thus allocate attention among uncompleted tasks [46]. Third, experimental research in social psychology on prospective memory shows that intrusions that compete for a subject's attention and enforce task switches, increase workload and reduce the ability to retain key aspects of the primary task upon resumption [47]. Finally, with respect to stress, intrusions adversely affected task demands via stressors that decreased emotional well-being of subjects doing secretarial work [20].

In NPD, intrusions are expected to strongly affect group workload, especially since tasks are complex to begin with [1] and workers have to juggle between multiple tasks. For instance, NPD group members engaged in collaborative product design using a CAD visualization system may be interrupted by a secondary task. This would increase group workload by limiting the time available for completing the design, imposing additional stress on the group, and prompting memory loss for some aspects of the design upon task resumption. Perlow [48] found that intrusions faced by a software engineering team spawned a perception of "time famine", where group members had to resort to implementing periods of quiet time to offset the increased workload pressures. Based, on the preceding theoretical and empirical evidence, we propose:

Proposition 2: Intrusions are positively associated with NPD group workload.

In contrast to intrusions, we posit no direct link between feedback interventions and group workload. Workload should not increase if there are associative cues between the primary task and the interrupt [47]. In this case, feedback interventions are not only associated to the primary task, but they directly cue the NPD group toward the source of discrepancy which allows them to better focus and more effectively complete the primary task without taxing their mental load. While this may suggest the presence of a negative link between feedback interventions and group workload, we resisted the temptation to propose a negative link since interventions do not necessarily reduce stress (one of the three components of workload). In fact, feedback interventions can in some cases enhance workload-related stress [35].

3.3. Feedback interventions & collective mind

A central thesis of this paper is that interruptions in the form of feedback interventions can directly influence cognitive capacity. According to capacity theory, attentional resources are allocated to a given task, within the bounds of overall capacity [16]. Hence, cognitive capacity refers to the stock of attentional resources that can be channeled to a given task.

As mentioned earlier, prior research has mostly presented the link between interruptions and cognitive capacity indirectly, by positing that interruptions increase task demand, while cognitive capacity can allocate attentional resources to the task to mitigate the adverse effect of interruptions [10, 13]. However, we have suggested earlier that feedback interventions can directly influence cognitive capacity, by providing new information that is directly relevant to completing the primary task [14, 18, 23]. According to capacity theory, capacity is not fixed but can be expanded by certain information processing modes [16].

One way that cognitive capacity can be enhanced by interruptions is via the notion of "mindfulness" [18, 49]. Mindfulness involves paying attention to situations and contexts, actively attending to new information, openness to different views, heedfully interrelating actions, and focusing on process rather than outcome [49]. The information provided by feedback interventions involves new events that allow NPD group members to expand existing cognitive capacity and switch to a more mindful mode of information processing [14, 18]. According to control theory and the literature on feedback [31], when specific task-related feedback reveals a discrepancy in performance, a state of enhanced attention is created, where cognition, motivation, and effort are channeled toward the source of discrepancy. Such mindfulness is especially triggered if the intervention contains new, unexpected information [18].

A group-level perspective can be adopted for both feedback interventions [40] and cognitive capacity [50]. First, we do not focus on individual feedback interventions (e.g., a performance report for an individual group member), but rather, on the aggregate effect for the NPD group. Examples of group-level discrepancies may include an inquiry on a failed prototype testing, which requires redirecting the attention of the NPD group toward resolving that issue. Second, collective cognition theories, such as distributed cognition theory and collective mind [50] allow us to conceptualize cognitive capacity at the group-level. Indeed, recent research has used distributed cognition theory to study the effect of interruptions on collective cognitive capacity [23]. In our context, we suggest that mindfulness as cognitive capacity is manifested at the group-level as the group's collective mind, defined as *a pattern of heedful interrelation of actions among group members* [50].

Feedback interventions activate the group's collective mind. They provide group members with windows of opportunity to refocus on the primary task, discuss sources of discrepancy, and better perform the task through collective action [19]. As an example in NPD, a performance report that reveals a discrepancy in the results of a prototype test is likely to interrupt the ongoing task and direct the attention of the NPD group toward the source of discrepancy. Group members with highly interdependent activities are motivated to learn about and fix the problem. Since that discrepancy could come from many sources such as a faulty product design, wrong elicitation of customer requirements, process engineering inefficiencies, and so forth, the interruption is then likely to activate a collective information processing mode where group members mindfully attend to the new information, heedfully interrelate their actions, and carefully attend to contextual cues in order to resolve the issue. NPD group members' actions are thus guided by an increased awareness of how their own efforts are related to those of others.

Although this link has not been tested empirically, some studies provide implicit support. For instance, it was found that formal interventions helped focus a group's attention and efforts on improved ways of collectively completing the task [5]. Similarly, when groups working in a coordinated fashion were given feedback that revealed a discrepancy in performance, they were motivated to increase their efforts and "work smarter – not only harder" [52: pp. 314].

Proposition 3: Feedback interventions are positively associated with the NPD group's collective mind.

3.4. IT usage and knowledge integration

The NPD process is complex and wide-scoped [1]. Knowledge for various tasks is fragmented and distributed throughout the firm. IT is used to facilitate the integration of such dispersed knowledge, by transgressing physical and temporal boundaries, mapping expertise, and providing a common platform that allows NPD group members to reconfigure and build on each others' knowledge. For instance, workflow technologies disseminate documents and directives that aid knowledge integration [7]. Knowledge repositories allow NPD group members to draw on their own as well as on others' critical task-related knowledge [33]. Similarly, IT-enabled knowledge networks (e.g., online discussion forums) allow distributed NPD group members to draw on an extended base of expertise useful for their projects. While empirical evidence is still scant, some support for this relationship can be discerned from the literature. For instance, knowledge management systems positively influenced organizational learning [53], and knowledge application in NPD [54]. Also, it was found that IT use for knowledge management positively affects the NPD group's ability to acquire, assimilate, transform, and utilize knowledge [33].

Proposition 4: IT use in NPD is positively associated with knowledge integration among the group.

3.5. Group workload, collective mind & knowledge integration

Both heedfully interrelating individual actions (collective mind) and combining disparate knowledge elements (knowledge integration) can be impeded by various aspects of group workload defined earlier, including mental demand, time pressure, and stress. NPD group members under high workload resulting from intrusions are less likely to expend the necessary cognitive resources required for such forms of collective cognition. First, increased mental demands induce group members to work more independently [48], seek established knowledge structures and retreat to overlearned situations [55]. Empirically, it was shown that intrusions occurring among healthcare groups increased demands with resulting breakdowns in communication and coordination [56].

Second, the temporal aspect of group workload also impedes collective mind and knowledge integration. With increased time pressure, group members – in an effort to conserve cognitive resources – are less likely to engage in effortful thought requiring interrelating thought patterns, and more likely to resort to less information processing, initial impressions, and reliance on simple and general knowledge structures [55]. Knowledge integration is complex, costly, slow, uncertain, and requires significant cognitive effort [1]. Hence, it becomes undesirable or unattainable at high temporal pressures resulting from intrusions. Indeed, individuals under time pressure reduce external information search and constrain efforts to stable internal evaluations [57]. A study of NPD groups found that constant interruptions with new information impeded group members' knowledge integration from external sources [58]. Perlow's [48] classic study of NPD software engineers also demonstrates that under time pressure group members collaborate less and even shut themselves out from interrelating their work with that of others through periods of "quiet time".

Third, it is not only actual lack of time that causes aversion of collective cognition, but also the stress resulting from increased group workload, which leads to reliance on less cues and simpler knowledge structures [59]. It was found that both individuals and groups under stress revert to information processing that is well-learned, less cognitively demanding, less newly derived, and leading to closing up, rather than opening up the group's cognitive interactions [14]. Hence, we propose the following:

Proposition 5: Group workload is negatively associated with collective mind.

Proposition 6: Group workload is negatively associated with knowledge integration.

3.6. Collective mind & knowledge integration

Collective mind enables knowledge integration. By heedfully interrelating their continuing day-to-day actions, NPD workers can be better at combining their multiple sources of dispersed expertise while being aware of the commonalities and idiosyncrasies of others' contributions. It seems reasonable to assume that paying attention to new situations and contexts, carefully reviewing new information, being open to new stimuli, and acting with heed with respect to others' ideas and actions are all qualities that may enable effective knowledge integration. Earlier, we defined collective mind as a collective cognitive capacity. Integrating dispersed NPD knowledge fragments requires vast attentional resources, and restrictions to such capacity limits knowledge integration [1, 60]. Such resources are afforded by the group's collective mind.

Although not directly tested, theoretical and empirical evidence in the literature implicitly supports such a link between collective mind and knowledge integration. For instance, Nonaka [61] argued that individual cognitive capacities are leveraged and combined to influence organizational knowledge creation. Furthermore, drawing on Grant [1], Huang and Newell [62] conceptualized collective mind as a pattern of continuous practice by NPD group members to enable seamless coordination between their actions. They found that such a collective mind enhanced the efficiency of the group's knowledge integration efforts. Another study showed that collective mind mediates the impact of social identity on knowledge integration among organizational units [63]. A survey of self-managing groups revealed that groups characterized by a "high-care" atmosphere are better at knowledge transfer and creation [64].

Proposition 7: The NPD group's collective mind is positively associated with knowledge integration.

3.7. Moderating effects

Interruptions have an impact on the immediate task at hand [10]. But in a process such as NPD, members are typically multitasking and this is greatly enabled by the use of IT. Hence, in this context an interruption may affect several tasks simultaneously. For instance, a feedback intervention, while having a positive effect

on a particular task as group members address the source of the discrepancy, may negatively intrude on other tasks that are left behind. However, such a spill-over effect occurs mostly if group members have low multitasking ability. Indeed, McFarlane [21] observed that individuals with higher multitasking abilities were able to mentally simulate their interrupted tasks, and to better handle them upon resumption. Similarly, Nagata (2006) found a positive moderation effect of multitasking ability on the link between instant messaging intrusions on a mobile device and web task performance. A high multitasking ability allows group members to adequately manage their tasks and minimize the adverse spill-over effects that one interruption may have on other tasks in their portfolios.

Proposition 8: Multitasking ability negatively moderates the effect of intrusions on group workload.

Task demand is decreased when interruptions occur at subtask boundaries [9]. Such control of interruption timing can be afforded by IT-based context awareness (e.g., a system that detects group members' availability and workload). Indeed, it was found that awareness display systems helped team members mitigate the influence of intrusions by initiating their information requests when other members were less busy [15]. Similarly, a study of healthcare physicians found that these were able to have better workload distribution when their interruptions were regulated through the use of electronic whiteboards that provided situational awareness of their tasks [22].

Proposition 9: Context awareness systems negatively moderate the effect of intrusions on group workload.

4. Discussion

Before discussing the implications of the paper, some limitations are mentioned. First, our framework omitted interruptions that are not caused by IT, such as organizational disruptions (strikes, restructuring, etc.) and structural group changes. While we recognize that a myriad interruptions could be included, this paper constrained the analysis to IT-induced ones since our interest was on how IT use influences knowledge integration in the context of interruptions. Yet, our definition is broad enough to incorporate non-IT induced interruptions. Second, only two interruption types were considered. While this has limited the scope of the discussion to something more manageable, we recognize that other interruptions (e.g., breaks and distractions) may have alternate effects on the NPD group (although they may be less applicable to the group-level, and may be internal). Third, we did not theorize on the influence of interruptions on NPD performance. As mentioned earlier, task performance has been amply covered in the literature, and we believe there are other interesting paths to knowledge processes and outcomes that should also be focused on.

These limitations notwithstanding, this paper has several implications for theory and practice. It provides a better understanding of how NPD knowledge integration, which is critical to NPD performance, is influenced by IT use. An underresearched form of impediment to knowledge integration has been examined; namely interruptions to group work. We have argued that IT use directly enhances knowledge integration, but that it also has an indirect effect via two alternate interruption paths that either facilitate or inhibit NPD knowledge integration. What determines the impact of this partial mediating effect is whether the interruption diverts group members from their primary task (intrusion), or refocuses them on the task (feedback intervention). In the former case, group members become cognitively overloaded and revert to simple knowledge structures requiring less effort, whereas in the latter they experience an enhanced collective mind that facilitates knowledge integration. Our approach extends the extant literature by focusing on group-level effects of interruptions, positive and negative impacts of interruptions, organizational settings rather than simulated problem-solving, as well as by suggesting new insights from looking at the cumulative effects of IT, task demand, and cognitive capacity in interruptions research. Most prior research has either overlooked the role of IT in interruptions [5, 13, 14], or held the effects of IT constant by examining a specific technology [9, 10, 34]. Instead, we explicitly model the role of specific NPD-related IT usage and examine its effects on various types of interruptions.

This framework is also useful to guide practitioners on the use of IT to facilitate knowledge integration in their NPD groups. Specifically, IT should be used as to mitigate the effects of intrusions and leverage the benefits of feedback interventions. First, NPD group members should electronically store information about their projects that is of sufficient quality and specificity as to reduce the likelihood of being interrupted with requests for information and clarification (intrusions). Second, discussions on the intrusive information requests can be stored in the repository along with the original information to minimize future intrusions. Third, better indexing and search technologies can be used to improve retrieval and reduce intrusions [27]. Fourth, IT can be used to control the timing of interruptions [15]. Finally, the information should be detailed enough to allow for receiving feedback interventions that better reorient group members toward successfully completing the primary task.

5. References

[1] R.M. Grant, "Prospering in dynamically-competitive environments: Organizational capability as knowledge integration", *Organization Science,* vol. 7, 1996, pp. 375-387.

[2] R. Patnayakuni, A. Rai, and A. Tiwana, "Systems development process improvement: A knowledge integration perspective", *IEEE Transactions on Engineering Management,* vol. 54, 2007, pp. 286-300.

[3] L.P. Robert, A.R. Dennis, and M.K. Ahuja, "Social Capital and Knowledge Integration in Digitally Enabled Teams", *Information Systems Research,* vol. 19, 2008, pp. 314-334.

[4] B.E. Munkvold, "Challenges of IT implementation for supporting collaboration in distributed organizations", *European Journal of Information Systems,* vol. 8, Dec, 1999, pp. 260-272.

[5] G. Okhuysen and K. Eisenhardt, "Integrating knowledge in groups: How formal interventions enable flexibility", *Organization Science,* vol. 13, 2002, pp. 370-386.

[6] S. Nambisan, "Information systems as a reference discipline for new product development", *MIS Quarterly,* vol. 27, 2003, pp. 1-18.

[7] M. Alavi and D.E. Leidner, "Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues", *MIS Quarterly,* vol. 25, 2001, pp. 107-136.

[8] J. Rennecker and L. Godwin, "Delays and interruptions: A self-perpetuating paradox of communication technology use", *Information Organization,* vol. 15, 2005, pp. 247-266.

[9] E. Cutrell, M. Czerwinski, and E. Horvitz, "Notification, disruption, and memory: Effects of messaging interruptions on memory and performance," in *Human-Computer Interaction - INTERACT'01 Conference Proceedings*, Amsterdam, 2001, pp. 263-269.

[10] C. Speier, J.S. Valacich, and I. Vessey, "The effects of task interruption and information presentation on individual decision making," in *Proceedings of the 18th International Conference on Information Systems*, 1997, pp. 21-36.

[11] F. Beeftink, W. van Eerde, and C.G. Rutte, "The Effect of Interruptions and Breaks on Insight and Impasses: Do You Need a Break Right Now?", *Creativity Research Journal,* vol. 20, 2008, pp. 358-358.

[12] N. Madjar and C.E. Shalley, "Multiple Tasks' and Multiple Goals' Effect on Creativity: Forced Incubation or Just a Distraction?" *Journal of Management,* vol. 34, 2008, pp. 786-805.

[13] B. Gong, "Managing interruptions: The role of fit between task demands and capacity", Unpublished doctoral dissertation, University of Pittsburgh, 2006.

[14] M.E. Zellmer-Bruhn, "Interruptive Events and Team Knowledge Acquisition", *Management Science,* vol. 49, 2003, pp. 514-528.

[15] L. Dabbish and R.E. Kraut, "Controlling interruptions: awareness displays and social motivation for coordination," in *Proceedings of the 2004 ACM conference on Computer supported cooperative work*, Chicago, 2004, pp. 182-191.

[16] D. Kahneman, *Attention and Effort*. Englewood Cliffs, NJ: Prentice Hall, 1973.

[17] T. Gillie and D. Broadbent, "What makes interruptions disruptive? A study of length, similarity, and complexity", *Psychological Research,* vol. 50, 1989, pp. 243-250.

[18] Q.R. Jett and J.M. George, "Work Interrupted: A Closer Look at the Role of Interruptions in Organizational Life", *Academy of Management Review,* vol. 28, 2003, pp. 494-507.

[19] N. Staudenmayer, M. Tyre, and L. Perlow, "Time to Change: Temporal Shifts as Enablers of Organizational Change", *Organization Science,* vol. 13, 2002, pp. 583-597.

[20] F.R.H. Zijlstra, R.A. Roe, A.B. Leonora, and I. Krediet, "Temporal factors in mental work: Effects of interrupted activities", *Journal of Occupational and Organizational Psychology,* vol. 72, 1999, pp. 163-185.

[21] D.C. McFarlane, "Comparison of Four Primary Methods for Coordinating the Interruption of People in Human-Computer Interaction", *Human-Computer Interaction,* vol. 17, 2002, pp. 63-63.

[22] D.J. France, S. Levin, R. Hemphill, K. Chen, D. Rickard, R. Makowski, I. Jones, and D. Aronsky, "Emergency physicians' behaviors and workload in the presence of an electronic whiteboard", *International Journal of Medical Informatics,* vol. 74, 2005, pp. 827-837.

[23] T. Grundgeiger and P. Sanderson, "Interruptions in healthcare: Theoretical views", *International Journal of Medical Informatics,* vol. 78, 2009, pp. 293-307.

[24] D. Dougherty, "Interpretive Barriers to Successful Product Innovation in Large Firms", *Organization Science,* vol. 3, 1992, pp. 179-202.

[25] W.J. Orlikowski, "Learning from Notes: organizational issues in groupware implementation," in *Proceedings of the 1992 ACM Conference on Computer-Supported Cooperative Work*, Toronto, 1992, pp. 362-369.

[26] M.M. Wasko and S. Faraj, "Why Should I Share? Examining Social Capital and Knowledge Contribution in Electronic Networks of Practice", *MIS Quarterly,* vol. 29, 2005, pp. 35-57.

[27] F. Olivera, P.S. Goodman, and S. Swee-Lin Tan, "Contribution behaviors in distributed environments", *MIS Quarterly,* vol. 32, 2008, pp. 23-42.

[28] G. Mark, V.M. Gonzalez, and J. Harris, "No task left behind? Examining the nature of fragmented work," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Portland, Oregon, 2005, pp. 321-330.

[29] J.B. Spira and J.B. Feintuch, "The cost of not paying attention: How interruptions impact knowledge worker productivity," 2005.

[30] D.W. Straub and R.J. Welke, "Coping with Systems Risk: Security Planning Models for Management Decision Making", *MIS Quarterly,* vol. 22, 1998, pp. 441-469.

[31] D. Ilgen, C.D. Fisher, and M.S. Taylor, "Consequences of individual feedback on behavior in organizations", *Journal of Applied Psychology,* vol. 64, 1979, pp. 349-349.

[32] J.R. Galbraith, *Organizational Design*. Menlo Park, CA: Addison Wesley, 1977.

[33] P.A. Pavlou and O. El Sawy, "From IT Leveraging Competence to Competitive Advantage in Turbulent Environments: The Case of New Product Development", *Information Systems Research,* vol. 17, 2006, pp. 198-227.

[34] T. Jackson, R. Dawson, and D. Wilson, "The cost of email interruption", *Journal of Systems and Information Technology,* vol. 5, 2001, pp. 81 - 92-81 - 92.

[35] S. Ang, L.L. Cummings, D.W. Straub, and P.C. Earley, "The Effects of Information Technology and the Perceived Mood of the Feedback Giver on Feedback Seeking", *Information Systems Research,* vol. 4, 1993, pp. 240-261.
[36] H.A. Simon, "Designing organizations in an information-rich world," in *Computers, Communication, and the Public Interest*, M. Greenberger, Ed. Baltimore: John Hopkins Press, 1971, pp. 37-52.
[37] M.T. Hansen and M.R. Haas, "Competing for Attention in Knowledge Markets: Electronic Document Dissemination in a Management Consulting Company", *Administrative Science Quarterly,* vol. 46, 2001, pp. 1-28.
[38] U. Schultze and B. Vandenbosch, "Information Overload in a Groupware Environment: Now You See It, Now You Don't", *Journal of Organizational Computing and Electronic Commerce,* vol. 8, 1998, pp. 127-148.
[39] A. Edmunds and A. Morris, "The problem of information overload in business organisations: a review of the literature", *International Journal of Information Management,* vol. 20, 2000, pp. 17-28.
[40] D.A. Nadler, "The effects of feedback on task group behavior: A review of the experimental research", *Organizational Behavior and Human Performance,* vol. 23, 1979, pp. 309-338.
[41] J. Hahn and M. Subramani, "A framework of knowledge management systems: Issues and challenges for theory and practice," in *Proceedings of the 21st International Conference on Information Systems*, Brisbane, 2000, pp. 302-312.
[42] C.A. Bowers, C.C. Braun, and B.B. Morgan, Jr., "Team Workload: Its Meaning and Measurement," in *Team Performance Assessment and Measurement: Theory, Methods and Applications*, M. T. Brannick, E. Salas, and C. Prince, Eds. Hillsdale, NJ: Lawrence Elbaum Associates, 1997, pp. 85-108.
[43] S.G. Hart and L.E. Staveland, "Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research," in *Human Mental Workload*, P. A. Hancock and N. Meshkati, Eds. Amsterdam: North Holland Press, 1988, pp. 139-183.
[44] J. Gluck, A. Bunt, and J. McGrenere, "Matching attentional draw with utility in interruption," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, San Jose, 2007, pp. 41-50.
[45] J.G. Trafton, E.M. Altmann, D.P. Brock, and F.E. Mintz, "Preparing to resume an interrupted task: effects of prospective goal encoding and retrospective rehearsal", *International Journal of Human-Computer Studies,* vol. 58, 2003, pp. 583-603.
[46] S.L. Kirmeyer, "Coping with competing demands: interruption and the type A pattern", *The Journal of Applied Psychology,* vol. 73, 1988, pp. 621-9.
[47] M.B. Edwards and S.D. Gronlund, "Task Interruption and its Effects on Memory", *Memory,* vol. 6, 1998, pp. 665-665.
[48] L.A. Perlow, "The Time Famine: Toward a Sociology of Work Time", *Administrative Science Quarterly,* vol. 44, 1999, pp. 57-81.
[49] E.J. Langer, *Mindfulness*. Reading, MA: Addison-Wesley, 1989.
[50] K.E. Weick and K.H. Roberts, "Collective Mind in Organizations: Heedful Interrelating on Flight Decks", *Administrative Science Quarterly,* vol. 38, 1993, pp. 357-381.
[51] E. Hutchins, "The social organization of distributed cognition," in *Perspectives on Socially Shared Cognition*, L. B. Resnick, J. Levine, and S. D. Teasley, Eds. Washington, D.C.: American Psychological Association, 1991.
[52] D.J. Mesch, J.-L. Farh, and P.M. Podsakoff, "Effects of Feedback Sign on Group Goal Setting, Strategies, and Performance", *Group Organization Management,* vol. 19, 1994, pp. 309-333.
[53] J.E. Scott, "Facilitating interorganizational learning with information technology", *Journal of Management Information Systems,* vol. 17, 2000, pp. 81-113.
[54] M. Song, C. Droge, S. Hanvanich, and R. Calantone, "Marketing and technology resource complementarity: An analysis of their interaction effect in two environmental contexts", *Strategic Management Journal,* vol. 26, 2005, pp. 259-276.
[55] M.F. Kaplan, L.T. Wanshula, and M.P. Zanna, "Time pressure and information integration in social judgment," in *Time Pressure and Stress in Human Judgment and Decision Making*, O. Svenson and J. Maule, Eds. New York, NY: Plenum, 1993, pp. 255-267.
[56] Y. Ren, S. Kiesler, and S.R. Fussell, "Multiple Group Coordination in Complex and Dynamic Task Environments: Interruptions, Coping Mechanisms, and Technology Recommendations", *Journal of Management Information Systems,* vol. 25, 2008, pp. 105-130.
[57] J.S. Hulland and D.N. Kleinmuntz, "Factors influencing the use of internal summary evaluations versus external information in choice", *Journal of Behavioral Decision Making,* vol. 7, 1994, pp. 79-102.
[58] D.G. Ancona and D.F. Caldwell, "Bridging the Boundary: External Activity and Performance in Organizational Teams", *Administrative Science Quarterly,* vol. 37, 1992, pp. 634-665.
[59] O. Svenson and A. Edland, "Change of preferences under time pressure: choices and judgements", *Scandinavian Journal of Psychology,* vol. 28, 1987, pp. 322-330.
[60] M.C. Becker and F. Zirpoli, "Organizing new product development: Knowledge hollowing", *International Journal of Operations & Production Management,* vol. 23, 2003, pp. 1033 - 1061-1033 - 1061.
[61] I. Nonaka, "A dynamic theory of organizational knowledge creation", *Organization Science,* vol. 5, 1994, pp. 14-37.
[62] J.C. Huang and S. Newell, "Knowledge integration processes and dynamics within the context of cross-functional projects", *International Journal of Project Management,* vol. 21, 2003, pp. 167-176.
[63] A. Willem, H. Scarbrough, and M. Buelens, "Impact of coherent versus multiple identities on knowledge integration", *Journal of Information Science,* vol. 34, 2008, pp. 370-386.
[64] C. Zarraga and J. Bonache, "The Impact of Team Atmosphere on Knowledge Outcomes in Self-managed Teams", *Organization Studies,* vol. 26, 2005, pp. 661-681.