Inter-sector Backup Behaviors in Parallel Approach ATC: The Effect of Job Satisfaction

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Abstract. Inter-sector cooperation between air traffic controllers (ATCos) can provide an effective way to manage controllers' workload by redistributing individual task-load at a group level, yet this area has not been fully explored. Based on our previous studies which have identified the effects of certain task-level features, this present research aimed to identify the influence of individual difference variables on controllers' backup decisions. Forty licensed controllers performed thirty-two simulated final approach scenarios in which they had to decide whether to accept a hand-over request made by a controller working in the neighboring sector. We manipulated three key task-level features across scenarios: (1) participants' task-load, (2) the requestors' task-load and (3) the close-landing demands of the to-be-hand-over aircraft. We also measured controllers' work experience and job satisfaction. HLM analysis showed that: after controlling for the effects of task-level variables, job satisfaction had a unique contribution and also interacted with task-level variables in predicting backing up behaviors.

Keywords: Air traffic control · Inter-sector cooperation · Job satisfaction

1 Introduction

Ground-based air traffic controllers (ATCos) play a crucial role in guaranteeing airline efficiency and safety. This is especially the case as airspace saturation, and personnel shortage is becoming more salient [1]. Previous research has made valuable efforts to manage controller's workload from an individual-focused or with-in sector approach [2–7], but the cooperation between sectors is less investigated. While inter-sector cooperation or backup behaviors can help redistribute task load so overload at an individual level can be prevented, factors that can influence such acts have not been thoroughly investigated in the ATC domain.

Considered to be critical for effective team performance, backing up behaviors refers to helping other team members perform their roles [8]. In previous studies in the non-ATC domain, it has been found that in deciding whether to offer backup,

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participants consider both their teammates' situation as well as their conditions [8–10]. Perceived workload and legitimacy are two important proximal predictors of backup behaviors. It is quite apparent that when helpers are under lower workload, they are more likely to make backup decisions. This is because the cognitive resource of the helpers is limited, they cannot offer any hand before finishing their own work. "The Legitimacy of need" was considered as the intersection of workload and capacity, and a positive relationship between the legitimacy of need and backing up behaviors was found in [8]. In a highly legitimate condition, for example, when the teammate is under high pressure, he/she will be more likely to receive backup from others.

However, to shed more light on our understanding of the backup behavior in the ATC domain, it is essential to explore how these two proximal factors are influenced by other more distal task and individual factors in the ATC domain. In the ATC domain, a typical inter-sector backup request happens when a controller (the requestor) asks his/her neighboring controller (the helper) to take-over the control of a certain amount of aircraft. The requestor should have managed these aircraft and accepting this request is beyond the helper's own duties and responsibilities. In this situation, the helper needs to decide on whether to take these aircraft or not.

There are many forms of inter-sector backup (e.g., between two neighboring en-route controllers, an en-route controller and an approach controller, and two approach controllers). Through interviewing professional expert controllers, we found that the cooperation between two parallel final approach sectors was among the most important situations in real practice. Such a configuration is common for large airports which have multiple independent runways. In a typical pair involving two parallel approach sectors, two final approach controllers manage two adjacent runways and nearby airspaces. Since the landing and take-off of aircraft in one runway can't interfere that of another, the controllers independently conduct their work. However, in certain conditions, one controller may find he/she cannot effectively manage the aircraft in his/her own sector and requests to hand over some planes in his/her sector to another one's. Facing this request, the neighboring controller needs to decide whether to accept or not. Several task properties have been further identified to influence the backup decision-making process: (1) the task load of the controller being requested, (2) the requestors' task load, and (3) the close landing demand of the to-be-hand-over aircraft.

The first factor was hypothesized to have a negative effect on one's willingness to provide backup. The reason is quite obvious as controllers need to manage their sector first. From the perspective of the Attentional Resource Theory [11, 12], if their task has highly occupied people, they cannot have additional resources to provide help to their colleagues. Indeed, lending hands to others may reduce their task performance [9]. Moreover, preventing overload is an important concern for this safety-critical occupation [5–7, 13–15]. As a result, we consider this variable to be the most important predictor of the backup decision. In experiments, this factor can be manipulated by aircraft count in the participants' sector [16–18].

The requestors' task load was hypothesized to have a positive effect on one's willingness to provide backup. This is because the controllers being requested will evaluate whether the request is reasonable. When the requestors' task load is high (e.g., many aircraft in his/her sector), his/her call for help can be perceived as legitimate. On the other hand, when the requestors' task load is low, his/her request for help can be perceived as social "loafing" or not genuine.

The close landing demand is a feature of the to-be-hand-over aircraft. When the taxiing distance of an aircraft can be reduced by being handed over to another controller's sector, we call this aircraft has a close landing demand. This happens because each airline company has its boarding gates. For example, if the boarding gates of a company are to the east, then when a plane of that company coming from the west would use the west runway for landing and taxi a quite long distance to reach its boarding gate. Of course, if such a plane can be handed over to the controller in charge of the east runway, it can land using the runway closer to its boarding gate. For controllers, this is not a requirement, but they tend to provide convenience for passengers and crews if they have enough mental capacity to deal with the overall situation. As a result, if the to-be-hand-over aircraft has a close landing demands, it is more reasonable to accept such a plane. So it is also hypothesized that controllers are more willing to accept airplanes with close-landing demands.

In a previous experiment that directly manipulated the three factors, it was found that all these task-level variables indeed influence controllers' backing up behaviors as hypothesized [19]. Specifically, the effect of controllers' task load on their backing up willingness and decisions was mediated by their perceived mental workload; the effect of the requestors' task load and the close landing demands was mediated by the perceived legitimacy of backing up requests. These findings provide initial evidence confirming the previously mentioned framework on controllers' backup behaviors. However, we also found that in addition to these task-level differences, there was a significant amount of unexplained variance that was between individual. Without a closer scrutiny of these individual differences, it is difficult to draw a firm conclusion about this behavior [2].

In the present study, we would focus on the individual difference factors that may also contribute to the decision-making process beyond the task-level factors by reanalyzing the previously collected data. Two factors will be examined in the current study. The first one is work experience. Work experience is considered as the most critical individual difference factor in ATC performance [3, 12, 20]. However, its effect on backup intentions is not self-evident. From an attentional resource perspective, controllers with more experience consume less cognitive resources in performing the same task as compared to novices. In this regard, the experienced controller might be more likely to provide backup because they have more surplus of resources to cope with other situation. However, there is also evidence that more experienced controllers also tend to make higher risk evaluation than their less experienced counterparts [3, 12]. In this way, they may think to provide help, i.e., bring additional risk to their airspace, might cause much more burden than their less experienced counterparts. Taken together, there is no substantial evidence to support a definite relationship between work experience and backup intentions. In this study, we will explore the effect of work experience on backup decisions.

The second one is job satisfaction, which is an evaluative state that expresses contentment with and positive feelings about one's job [21]. Indeed, providing inter-sector backup can be considered as a typical "citizenship" behavior, which was defined as behaviors that can "lubricate the social machinery of the organization" but beyond "the usual notion of task performance" [21]. A vast quantity of evidence collected from service industry supports a positive relationship between job satisfaction and citizenship [21, 22]. Experiencing a generalized positive mood from their work, people are more likely to make typical citizenship behaviors such helping their colleagues and serve their customers [23, 24]. Whereas there is no direct evidence concerning the ATCos, air traffic controller with a higher level of job satisfaction might be more willing to help their colleagues and serve the passengers. So we expected job satisfaction to have a positive effect on their back up decisions.

2 Method

2.1 Participants

Forty licensed controllers from a provincial ATC center in South China participated this experiment. Their ages ranged from 22 to 48 (M = 27.68, SD = 4.99), and work experience ranged from 1 to 20 years (M = 4.97, SD = 3.93). They were paid for this and one other sub-task at a total payment of 300 Yuan.

2.2 Task and Design

Parallel Final Approach Task. We used ATC-Simulator, a medium-fidelity air-traffic-control simulation platform for research purpose [25–27] in this study. The interface was designed to simulate two parallel sectors in final approach. In this experiment, participants were asked to manage the sector on the right while the left sector was handled by another controller (whose behaviors were previously programmed). As shown in Fig. 1, the area in dark grey was participants' sector in which participants were able to manipulate the aircraft, while the light grey area was their colleague's sector which participants were not able to control.

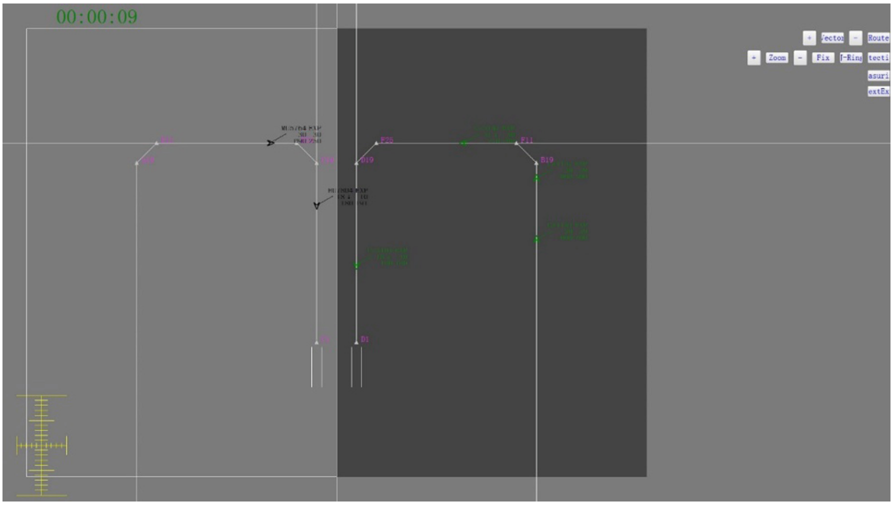

Fig. 1. The interface of the parallel approach simulator.

For each scenario, aircraft were flying into two final approach sectors. Each plane had a data block showing its call sign, flight level, bearing, and velocity. In the first 40 s, participants first needed to monitor and manage aircraft in their sector to make sure the minimum separation standard was never violated, and all the flight conditions were following the operational protocols. Then they were asked to assess their mental workload during the previous work. After that, participants were informed that the colleague managing the left sector requested to hand over one aircraft. They were asked (1) to what extent they were willing to accept this aircraft (from 1 for extremely low to 8 for extremely high, referred to as Backing-up Willingness below), and (2) if they would accept the to-be-handover aircraft or not (referred to as Backing-up Decision, Reject coded as 0 and Accept coded as 1). After completing both questions, participants were to perform the next scenario.

Aircraft were in conflict if they simultaneously violated both the lateral (5 nm) and vertical (1,000 ft) separation standard. Aircraft positions were updated every second. Two supportive tools were offered to help participants make decisions: (1) a 20 nm 10 nm scale maker in the bottom left corner which could be moved anywhere within the airspace; (2) a distance/time calculation function was provided. If participants hold down the left mouse button to select a plane and move it to any point on the screen, they would see the distance (in nautical miles) and time (in minutes) to reach that point (if maintaining the current velocity).

Scenarios. There were 38 scenarios in total, including the first six practicing scenarios and 32 formal scenarios. A 2 (*Participants' task load*: low vs. high) × 2 (*Requestor's task load*: low vs. high) × 2 (*Close landing demand:* no vs. yes*)* design was used thus creating eight different conditions. For each condition, four distinctive scenarios were created thus producing the overall 32 scenarios. *Participants' task load* was manipulated by aircraft count in the right sector. In the 16 low task-load scenarios, there were four aircraft; in the 16 high task-load scenarios, there were ten aircraft. *Requestor's task load* was manipulated by aircraft count in the left sector. In the 16 low task-load scenarios, there were 2 aircraft; in the 16 high task-load scenarios, there were 8 aircraft. *Close landing demand* was manipulated by the call sign of the plane indicating their company. At the beginning of the experiment, participants were told that the drop-off gates of Air China (CA) and China Southwest Airlines (SZ) were nearer to the right runway under their control. The other two signs (MU and HU) were representing companies whose boarding gates were nearer to the left runway under the control of their colleagues. As a result, in the 16 no close-landing demand scenarios, the aircraft to be handover had the call-sign such as or; in the 16 close landing demand scenarios, the planes had the call sign CA or SZ.

Measuring Individual Difference Factors. *Work experience*. Work experience was measured by self-report. Participants indicated how long they have worked as a professional controller. *Job satisfaction*. Participants' job satisfaction was measured by the 5-item Job Satisfaction Scale [28]. Participant needed to rate to what extent they agreed with the statement such as "I find real enjoyment in my work" on a 5-point-Likert scale (1 for strongly disagree and 5 for strongly agree). The Cronbach alpha coefficient of the scale was .86.

2.3 Procedure

Upon arrival, participants first read and signed a written informed consent form. Then they completed a series of questionnaires about demographic information and personality (including Job Satisfaction). After that, they were asked to sit at a computer with a 22-inch-wide LED monitor and start to learn how to perform the task through 6 teaching scenarios. Once familiarized, they completed all 32 scenarios in a random manner.

3 Result

3.1 Initial Analysis

Table 1 presents the means, standard deviations, and correlations for all variables.

Table 1. Correlation matrix of all variables

	Mean (SD)	1	2	3	4	5	6
1. Close-landing	.50 (.50)						
2. Task-load	7.00 (3.00)	–					
3. Requestor's Task-load	5.00 (3.00)	–	–				
4. Backing-up Willingness	3.72 (2.75)	.05*	−.64**	.15**			
5. Backing-up Decision	.54 (.49)	.08**	−.68**	.09**	−.72**		
6. Experience	4.97 (3.93)	–	–	–	.02	.06	
7. Job Satisfaction	3.59 (.87)	–	–	–	.13	.13	.13

* p < .05, ** p < .01

3.2 HLM Analysis

To examine the effects of scenario parameters and individual difference simultaneously, avoiding problems caused by missing data, we adopted hierarchical linear modeling (HLM) with the HLM 6.02 program [29]. Using HLM, we tested our hypothesis in a nested approach. First, a null model with only the dependent variable was established. We found the intra-class correlation coefficient (ICC) was 12.7% for the willingness of backing-up, and 15.5% for the backing-up decision, respectively. According to [30], this indicates there was quite a large amount of between individual variance. Second, we tested the effects of task-level variables (level 1predictors: Task-load, Requestor's Task-load, and Close Landing). Thirdly, we tested the main effects of the individual difference variables (level 2 predictors: work experience and Job Satisfaction) after controlling for the level predictors. Finally, we tested whether individual difference variables would interact with task-level variables.

HLM Results Predicting Backing-Up Willingness. In model 1 with task-level predictors, Task-load ($\beta = -.590$, $p < .01$), Requestor's Task-load ($\beta = .139$, $p < .01$), and Close Landing ($\beta = .315$, $p < .01$), turned out to be significant predictors of backing-up willingness. Controllers were more willing to accept the handover request when they were under low pressure, when their colleagues were at higher pressure and when the aircraft had a close-landing demand.

In model 2, the main effect of job satisfaction turned out to be a significant predictor (β = .426, p < .05), which means participants with higher job satisfaction were more willing to back up. Work experience, however, was not found to have a significant influence.

In model 3, it was found that Job Satisfaction had an interaction with Task-load (β = −.078, p < .05). We plotted such interaction in Fig. 2 to describe this moderating effect, based on the method recommended by [31]. It showed that Job satisfaction could improve controllers' backup intentions only when the task load is not high.

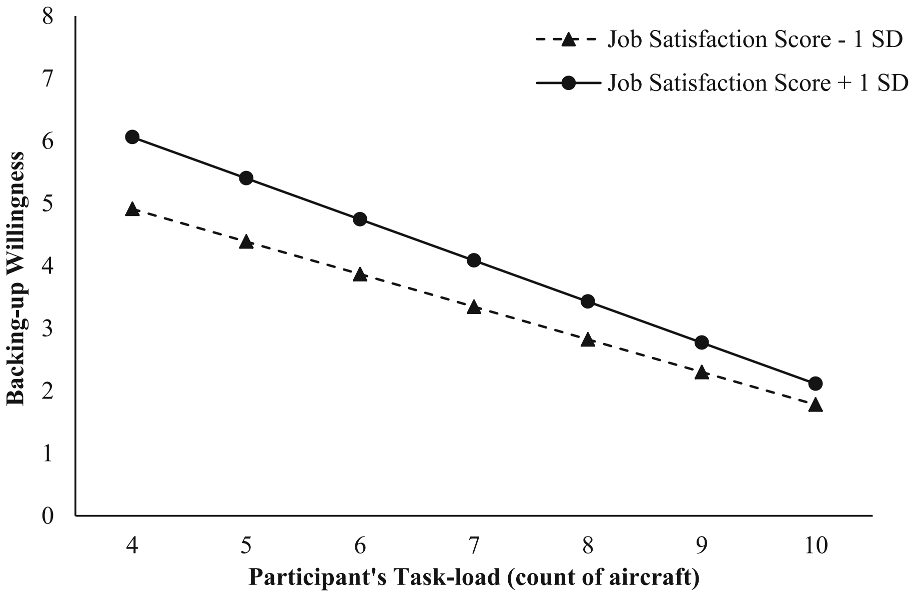

Fig. 2. The joint effect of Participant's Task-load and Job Satisfaction on Backing-up Willingness

HLM Results Predicting the Backing-Up Decision. In model 4 with task-level predictors, Task-load (β = −.602, p < .01), Requestor's Task-load (β = .121, p < .01), and Close Landing (β = .624, p < .01), turned out to be significant predictors of backing-up decisions. Controllers were more willing to accept the handover request when they were under low pressure, when their colleagues were at higher pressure and when the aircraft had a close-landing demand.

In model 5, the main effect of job satisfaction turned out to be a significant predictor (β = .605, p < .01), which means participants with higher job satisfaction were more willing to back up. Work experience, however, was not found to have a significant influence.

In model 6, it was found that Job Satisfaction had an interaction with Requestor's Task-load (β = −.085, p < .01). We plotted such interaction in Fig. 3 to describe this moderating effect, based on the method recommended by [31]. It showed that Job satisfaction could improve the possibility of controllers' backup only when requestor's task load is not high (Fig. 3).

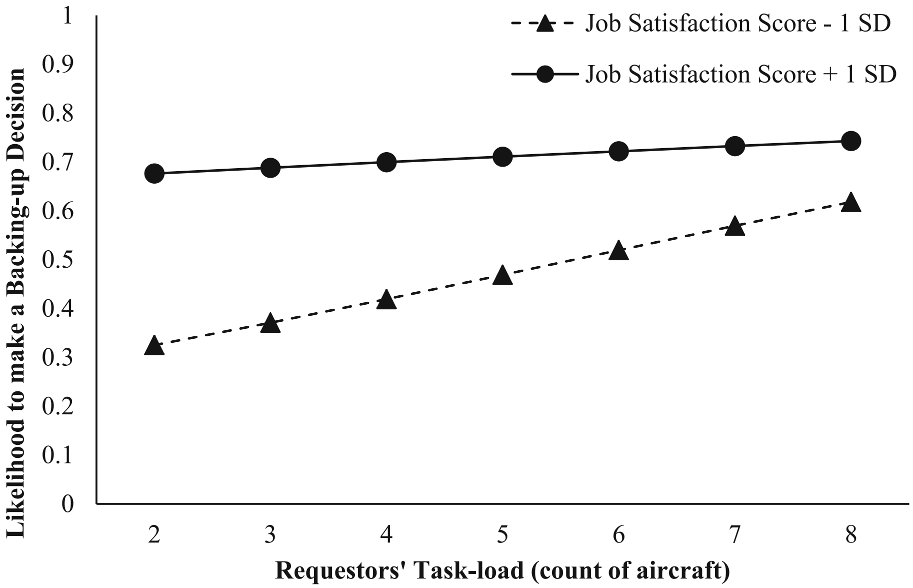

Fig. 3. The joint effect of Requestors' Task-load and Job Satisfaction on Backing-up Decision

Table 2. HLM results predicting Backing-up Willingness and Backing-up Decision

Parameters	Backing-up Willingness			Backing-up Decision (1 for accept, 0 for reject)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	3.716 (.16)**	3.716 (.16)**	3.716 (.15)**	.345 (.15)**	.366 (.19)$^{+}$	.387 (.18)*
Task level (N = 1280)						
Close Landing	.315 (.11)**	.315 (.10)**	.315 (.11)**	.624 (.16)**	.643 (.16)**	.652 (.16)**
Task-load	-.590 (.03)**	-.590 (.01)**	-.590 (.03)**	-.602 (.04)**	-.634 (.04)**	-.638 (.04)**
Requestor's Task-load	.139 (.02)**	.139 (.01)**	.139 (.02)**	.125 (.03)**	.129 (.03)**	.128 (.03)**
Individual level (N = 40)						
Experience		.004 (.04)	.004 (.03)		.050 (.06)	.051 (.06)
Job Satisfaction		.426 (.19)*	.426 (.16)*		.605 (.19)**	.588 (.18)**
Interaction						
Close Landing * Job Satisfaction			.195 (.10)			.057 (.16)
Task-load * Job Satisfaction			-.078 (.03)*			-.013 (.03)
Requestor's Task-load * Job Satisfaction			-.016 (.01)			-.085 (.02)**

$^{+}$ p < .10, * p < .05, ** p < .01

4 Discussion

Focusing on the inter-sector cooperation between air traffic controllers, this study sought to explore how individual difference variables can influence controllers' backing-up behaviors. First, we confirmed previous findings that the three task-level variables, controllers' task-load, backup requestors' task-load, and the close landing demands, significantly predicted controllers' backing-up willingness and decision. Controllers were more willing to accept the handover request when they were under low pressure, when their colleagues were at higher pressure and when the aircraft had a close-landing demand. This can be explained in the framework that controllers evaluate their resources as well as the legitimacy of their team members' request [7–9].

Second, we found job satisfaction had a positive effect on both backup willingness and final acceptance decisions. Consistent with the literature of organizational citizenship behavior, controllers who had a higher level job satisfaction tended to provide more help to their colleagues beyond their task [21–24]. Moreover, we found that there was some interesting interaction between job satisfaction and specific task-level variables. When controllers' own task-load was high, all controllers were not willing to back up, regardless of their job satisfaction. However, when their task-load decreased, the help willingness of controllers with a higher level of job satisfaction increased more. This result suggests that people satisfied with their jobs were not acting like a "good old man" who will sacrifice their duties to help others. Also, when backup requestors' task-load was high, all controllers backed up a lot. And the backing-up behaviors of controllers with a higher level of job satisfaction decreased less when requestors' task-load decreased. While backup requestors' task-load was very high, it is such a legitimate request that almost no controllers refused to help. But when requestors' task-load was relatively low, requestor's situation was not so pressing, only controllers with higher job satisfaction still chose to back up, suggesting their behavior may not depend on overt cues of social legitimacy. Such effect is vital as whether a controller is in real need may not be easy to detect. A difficult air traffic situation may not always involve many aircraft, and few aircraft can also result in high demand. In this way, a timely backup that is not solely driven by the simple cues of workload (aircraft count) may be necessary for the controller as a whole.

Several limitations must be addressed before making any conclusion. First, although we designed a quite real environment and invited a quite large sum of professional controllers to participant our experiment, the study was still apparently a simulation, and the participants' behavior might be different from their behaviors in real work settings. Future studies may go further to collect real operational data which may depict the actual backup behaviors. Nevertheless, it is always a difficult decision to balance the need for ecological validity and adequate experimental control. Second, we only measured their job satisfaction in its natural form and the very nature of the design is cross-sectional. It is possible that a third unmeasured factor influences both job satisfaction and backup behaviors. Future studies may benefit from using intervention techniques such a job crafting or workspace design to improve controllers' positive feelings toward their job. These methods not only provide more robust evidence regarding a causal effect but also make actual improvement possible.

5 Conclusion

In this study, we found evidence suggesting that job satisfaction could be a significant predictor of controllers' backup behaviors. The effect of positive job attitude is new in the domain of ATC and has important implications. Since workload management is important for controllers, the traditional individual-focused approach might reach its limit. It is important to find new variables that may have a positive effect to promote workload redistribution. Future studies may find ways to cultivate a better attitude toward one's work.

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