How Task Level Factors Influence Controllers' Backup Behavior: The Mediating Role of Perceived Legitimacy and Anticipated Workload

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Abstract. The volume of air traffic has increased considerably in recent years, and the task load of air traffic controllers (ATCos) is reaching a new high. Since the mental workload of ATCos is linked with both safety and efficiency of aviation, both researchers and practitioners are seeking novel methods to prevent overload. In this research, we adopted a new approach to understanding the workload management of ATCos by investigating how they made backup decisions. The aim of the research is to investigate the forms and mechanisms behind cross-sector backup of ATCos. Based on literature review and expert interview, we identified three task-level variables (task load of providers, task load of requestors, and close-landing demands of the to-be-hand-over aircraft) and two mediating variables (workload of participants and the perceived legitimacy of backup requests) that may influence controllers backup decisions in parallel runway operations, a typical and important form of ATCos cooperation. To validate this model, we conducted two studies. We invited licensed controllers to perform simulated final approach scenarios on a medium-fidelity ATC simulation platform. They had to decide whether to accept a hand-over request made by a controller working in the neighboring sector. In Study 1, three task-level variables (task load of participants, task load of requesters, and the close-landing demands of the to-be-hand-over aircraft) were manipulated, and two mediating variables (workload of participants and evaluations of the legitimacy of backup requests) were measured. HLM analysis firstly showed that task-level variables all significantly predicted backup decisions. Controllers were more willing to accept the request when they were under low pressure, when their colleagues were at higher pressure and when the aircraft had a close-landing demand. As for two mediating variables, participants perceived legitimacy of requests mediated the relationships between task-level variables and back-up decisions. However, the perceived current workload of participants did not mediate the impact of task variables on backup outcomes as expected. We proposed that it was the anticipated workload of controllers, not the perceived current workload of controllers, that played the mediating role. In Study 2, the anticipated workload of participants was measured in addition to the other two mediating variables. HLM analyses suggested that both perceived legitimacy and anticipated workload were mediators between task-level variables and back

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up decisions. In conclusion, this study identified several key psychological factors influencing ATCos cross-sector backup behaviors for the first time.

Keywords: Air traffic control · Parallel final approach · Cross-sector cooperation · Backup behaviors · Individual difference

1 Introduction

With the rapid development of the aviation industry, the current airspace is facing a saturation problem. Meanwhile, the shortage of air traffic controllers (ATCos) makes the situation even worse by casting too much workload to incumbent ATCos [23]. Since ATCos workload is an important constraint of aviation safety and efficiency, many studies had examined the factors that can predict or reduce controller's workload at an individual level [26–28, 35, 41, 46]. However, there is another way for controllers to manage their workload: receiving and providing backup to their teammates.

Backup behaviors are generally defined as helping other team members to perform their roles [8, 33]. Since it can compensate and redistribute the unbalanced resources at the team level, backup has been considered as one of the essential aspects of teamwork [31]. Studies have found evidence that backup behavior can improve team effectiveness [10, 36]. However, few studies have investigated the backup behavior in ATCos (for an exception study which used survey method, sees [49]).

In this study, we will focus on backup behaviors in typical and important cooperation: parallel runway operation (PRO) [11, 44]. PRO is common for ATCos who manage sectors around any large airport which has multiple runways. In performing a PRO, two approach controllers issue orders to pilots in their sectors to guide their queueing, landing and taking off using the runway in their sectors. At the same time, they have to pay attention to each other's sector because the wake stream caused by landing/taking off using one runway may influence the other [22]. In this operation, controllers often offer and provide backup. Typically, one controller (the requestor) may request a handover of a certain aircraft to the neighboring sector, and the controller of that adjacent sector (the provider) need to ponder whether to accept such handover request. Figure 1 illustrates the situation of a typical PRO and a backup situation. Since it is more important to understand why certain backup can be accepted, we would first review the factors that may influence the backup decisions of the provider.

1.1 Task Level Factors in Predicting Providers Backup Decision

The most important task-related variables that can influence providers backup behavior is the task-load of both the requestor and the provider [3, 39, 40]. Obviously, the providers are less likely to provide any backup if their task load is already very high [40]. From the perspective of cognitive resources theories [25, 37, 51], if the task requirement is beyond their cognitive capacity, the providers are not able to provide any back up because it may consume their resource to deal with their task and undermine their own task performance. Lots of studies showed that it is critical for the controllers to avoid overload since aviation safety is in the first place [7, 27, 28, 41, 45, 47]. Therefore,

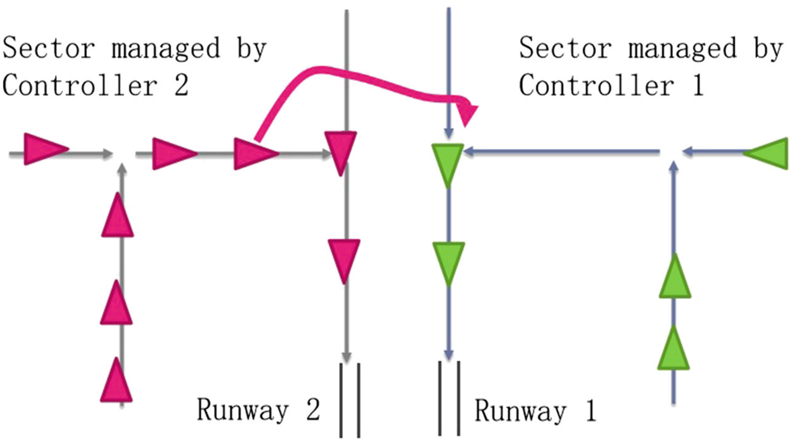

Fig. 1. The situation of a typical PRO and a backup situation

we speculate that the task load of backup providers is an important predictor of the backup decision. In ATC, the task load of a controller can be evaluated by the traffic complexity metrics which is often quantified by the number of aircraft in any given sector [18, 29, 32]. Accordingly, we proposed our first hypothesis:

H1. *The task load of backup providers, as quantified by the number of aircraft in the sector, is negatively related to the possibility of backup behaviors.*

It was also found that the providers were more likely to provide backup if the task load of the requestor is higher [3, 39, 40]. This is because the request must be considered reasonable by the provider to be accepted. If someone who makes a request for help but does not have much work to do, the provider may question his/her motivation and treat it as a form of social loafing [16, 34]. In this way, the task-load of the backup requestor is a signal showing the requestor has a genuine need, and that makes the provider willing to offer help. Accordingly, we proposed our second hypothesis:

H2. *The task load of backup requestors, also quantified by the number of aircraft in their sectors, is positively related to the possibility of backup behaviors.*

While the two abovementioned forms of task load are important in previous studies [3], we would discuss a new and unique factor that may have a great impact in influencing controllers' backup decision: the close-landing demands of the to-be-hand-over aircraft. We call that an aircraft has a close-landing demand if handing over such an aircraft to another sector can reduce the ground taxiing distance. This is because generally most commercial planes need to port on their own company's gates located on one side of the airport. However, these gates might be far away from the runway they landed if no transfer is made. For example, let us think company A's gates are located near the Runway 1 as shown in Fig. 1, then if a plane of company A is coming from the west, it should be managed by controller 2 and uses runway 2 to land. Therefore, it has to taxi a long distance to reach its gate. However, if such an aircraft is handed over from controller 2 to controller 1, the taxiing distance will be greatly shortened which may, in turn, reducing the waiting time of passengers and the costs of airline companies. In this situation, such a plane has a closing land demand. To note, it is not a formal requirement that all controllers must accept such kinds of aircraft. However, controllers may find it to be a good favor and may accept this kind of request in certain circumstances [13]. Therefore, accordingly, we proposed our third hypotheses:

H3. *The close-landing demands of to-be-hand-over aircraft are positively related to the possibility of backup behaviors. If an incoming aircraft has close-landing demand, backup providers are more willing to accept the backup request.*

1.2 The Mediating Variables

To better reveal the inner mechanism behind the backup decision-making process, we further listed two variables that may mediate the impact of three task-level variables previously mentioned.

The first mediating variable is mental workload. Whereas previous studies manipulated the actual task load by changing, for example, the number of targets, how the operators did perceive has not been measured. Mental workload is an important measure used in human factor studies which reflects the surplus of the operators' capacity as meeting the task demand. Often measure using subjective measures, the mental workload can provide additional explanatory power beyond actual task load since it also takes the capacity of the operator into account. The same level of task load (e.g., four aircraft in a sector) can result in different levels of mental workload upon controllers with different amount of cognitive resources. For example, an experienced controller may find it very easy to handle (low mental workload) while a novice may find it extremely hard (high mental workload). In this way, since mental workload reflects the unused resources to operating an addition task (i.e., backup), it may mediate the influence of providers task load on their backup behaviors.

H4. *The provider's mental workload mediates the influence of providers task load, as quantified by aircraft number, on backup behaviors.*

The second mediating variable is perceived legitimacy. Whereas mental workload reflects whether a controller is ABLE to provide backup, perceived legitimacy reflects whether a controller is WILLING to do so. Although such a concept has been raised by previous studies [3, 39, 40], it was only manipulated by the imbalance of task load rather than being directly measured. There are two problems to use such kind of manipulation. First, it is not known whether the backup behaviors are made due to a genuine feeling of legitimacy or fairness or just simply because they do not have the resource to do so. Second, it precludes other factors beyond task load imbalance that may also result in the feeling of legitimacy. For example, in our study, the existence of close-landing demand may also increase the legitimacy of the request since that is a good thing to do. As a result, in this study, we intended to measure this variable directly to see whether the provider has a feeling of legitimacy and whether such a feeling can mediate the influence of task-level factors (i.e., requestors task load and close-landing demand) and backup behaviors.

H5. *The perceived legitimacy of backup requests mediates the influence of requestors task load and close-landing demand on the possibility of backup behaviors.*

2 Study 1

In order to test our hypotheses, we manipulated the three task-level variables and measured the two mediating variables and conducted hierarchical linear modeling (HLM) to analyze the data.

2.1 Method

Participants. In total, 22 licensed professional air traffic controllers participated in this experiment. Their ages ranged from 24 to 48 years (M = 29.11, SD = 6.41) and ATC experience ranged from 2 to 20 years (M = 5.94, SD = 4.74). Due to equipment failure, only 18 were available for analysis. All participants were paid 150 RMB after completing this experiment. All participation was voluntarily and anonymously.

The Parallel Runway Operation Task and Scenarios. ATC-Simulator, a medium fidelity ATC simulation platform [12, 52–54], is used to simulate the parallel runway operation. In each scenario, there were two final approach sectors each of which contained a runway. All participants managed the sector on the right side of the screen, while the adjacent side on the left side was operated by another hypothetical ATCo performing the pre-planned operation. The sketch map is shown in Fig. 2. Each plane had a label showing its call sign, direction, altitude, course, and speed. Participants

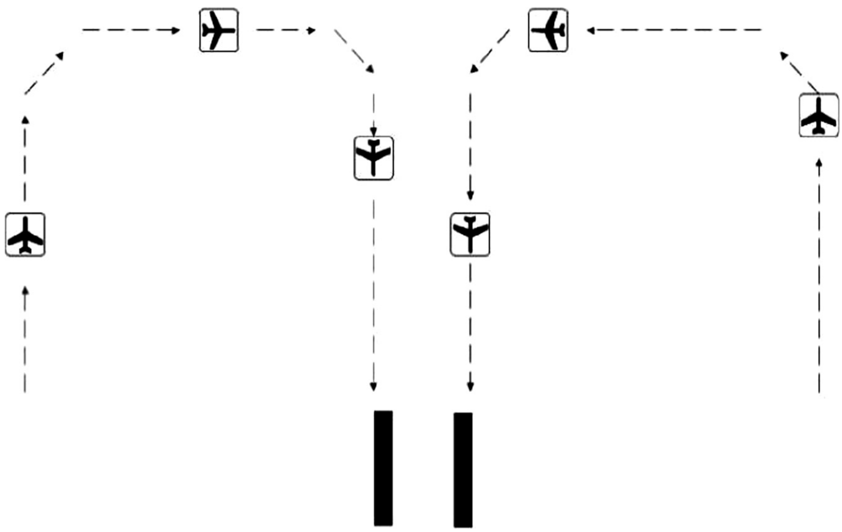

Fig. 2. Task parallel final approach interface

could use two supportive tools. One is a scale of 10 nm * 20 nm located in the lower left corner of the screen. The another is a distance/time calculation tool to get the distance and angle from the former point to the latter point and the angle, time and distance of aircraft flying from the current position to the point at current speed. The participants can see the conditions in both sectors, but they can only issue orders to aircraft in their own sectors.

At the beginning of each scenario, multiple aircraft appeared in both sectors, and the participants are required to constantly monitor and adjust the speed and altitude of the aircraft to fulfill the following three requirements: (1) do not violate the minimum separation standard (5 nautical miles level, 1000 ft vertical); (2) keep the speed of aircraft less than 200 knots and the altitude of aircraft less than 3000 ft when entering the Final; (3) keep a 5 min time interval between aircraft. This period lasted for 40 s, during which the participants were requested to make necessary interventions. After that, a series of dialog boxes popped up to collect the ratings of mental workload using the six items of NASA-TLX [20]. The average score of the six items was used as the mental workload ratings.

After answering these questions, the task was frozen, and the participants were told that the colleague of the neighboring sector wanted to hand over an aircraft due to certain reasons, and asked how they would think and respond to this request. In this process, participants could see their current flight situation and the to-be-handed-over aircraft, but they cannot make any interventions. Perceived legitimacy was measured by using an 8-point item "how legitimate do you think the request is?" (1 representing very low and eight very high). Backup willingness was measured by an 8-point item "how is your willingness to accept the handover aircraft" (1 representing very low and eight very high). The backup decision was measured by a dichotomous force choice. "Do you accept or reject the aircraft?" (0 representing rejection and one acceptance). When participants completed all the questions, they would enter the next scene.

The whole task had 38 scenarios, the first 6 were practice scenarios, and the remaining 32 were for formal experiments. The experiment used a 2 (participants task-load: low/high) * 2 (requestors task-load: low/high) * 2 (close-landing demand: have/no) within-subjects design, resulting in 8 different conditions and each condition contained 4 different scenarios.

The close-landing demand was manipulated by the call sign of the aircraft to be handed over. In the situation with a close-landing demand, the aircraft to be handed over will board to a gate near the participant's sector; in the situation without a close-landing demand, the aircraft to be handed over will board to a gate near the colleague's sector.

The task load of participants was manipulated by the number of aircraft in their sector. There were four aircraft in the low task load condition and 10 in the high task load condition. The task load of backup requestors was manipulated by the number of aircraft in the left sector. There were two aircraft in the low task load condition and 8 in the high task load condition.

Experimental Process. Upon arrival, the experimenter briefed all participants on the process of the experiment, and the participants signed the informed consent. Next, the participants were asked to remember several call signs of the airline companies and the locations of their gates (close to their sector or their colleague's sector). They were tested then to ensure all that information was accurately remembered. Afterward, they completed the six practice scenarios and 32 formal scenarios on a computer with a 23-in. monitor, which lasted about one hour. Participants reported demographics (sex, age, work experience) afterward and they were paid, thanked and debriefed.

2.2 Results

Basic Analysis. Table 1 provides the means (M), standard deviations (SD) the correlations of all variables. From the table, we can see that both backup wiliness and decisions were significantly correlated with the three task-level variables and the two mediating variables.

Table 1. Means, standard errors and zero-order correlations of all variables in study 1 (n = 18)

	M (SD)	1	2	3	4	5	6	7
1. Close-landing demand	.50 (.50)							
2. Task load of the provider	7.00 (3.01)	-						
3. Task load of the requestor	5.00 (3.01)	-	-					
4. Mental workload	2.28 (1.28)	−.01	.60**	.03				
5. Perceived legitimacy	3.58 (2.31)	.10*	−.58**	.24**	−.37**			
6. Backup willingness	3.73 (2.42)	.09*	−.62**	.17**	−.38**	.89**		
7. Backup decision	.43 (.45)	.09*	−.66**	.11**	−.37**	.63**	.68**	
8. Job experience	5.94 (4.74)	-	-	-	−.04	.07	.03	.05

Multilevel Regression Modeling. In order to test our hypotheses, we conducted multilevel regression modeling using HLM 6.08 software to analyze the data [43]. In performing the multilevel modeling, a null model with no predictors at both levels was built to test whether the data is suitable for multilevel analysis. The intra-class correlation (ICC) of backup willingness and backup behavior were 10.24% and 10.88%, respectively, suggesting the necessity to use the modeling approach [38].

Regression Models in Predicting Backup Willingness. Using backup willingness as the dependent variable, we constructed two nested models. In model 1, we put three task-level variables, close-landing demand, task-load of the provider, and task-load of the requestors, into the model. Job experience was also entered into the model as a control variable.

The results showed that the close-landing demand (β = .503, $p < .01$), task-load of providers (β = −.576, $p < .01$) and workload of requestors (β = .156, $p < .01$) all significantly predicted the backup willingness (see Table 2 for details). Specifically, participants were more willing to accept the aircraft if it had a close-landing demand when they own task-load was low and when requestor's task load was high. Therefore, H1 to H3 were all confirmed.

Table 2. HLM in Model 1

	Backup willingness		Backup decision (1 backup, 0 refuse)	
	Model 1	Model 2	Model 3	Model 4
Intercept	3.724** (.29)	3.724** (.29)	.503 (.63)	.542 (.31)
Individual level variable (N = 18)				
1. Job experience	.006 (.06)	.006 (.06)	.034 (.13)	.034 (.06)
Task level variable (N = 576)				
2. Close-landing demand	.503** (.14)	.076 (.09)	.711** (.22)	.545* (.16)
3. Provider's task load	−.576** (.02)	−.182** (.02)	−.590** (.04)	−.377** (.05)
4. Requestor's task load	.156** (.02)	−.011 (.01)	.147** (.03)	.059 (.04)
5. Perceived legitimacy		.778** (.02)		.426** (.07)
6. Mental workload		.023 (.06)		−.194 (.17)

Note: *p < .05, **p < .01

In model 2, the perceived legitimacy and mental workload were added into the model. The results showed that perceived legitimacy was a significant predictor of backup willingness (β = .778, p < .01), while mental workload had no significant influence (β = .023, *n.s.*). At the same time, the effects of the three task-level variables were all reduced. The close-landing demand was dropped from 0.053 to 0.076 (β = .076, *n.s.*), the task-load of the provider was dropped from 0.576 to 0.182 (β = −.011, *n.s.*) and task-load of the requestor was drop from 0.156 to 0.011 (β = −.182, p < .01). It means that perceived legitimacy mediated the influence of all three task-level variables on the backup willingness. Therefore, H4 was not confirmed, but H5 was confirmed.

Regression Models in Predicting Back-Up Decision-Making. Using backup decision-making as the dependent variable, we constructed two nested models which were similar to multilevel regression modeling using HLM 6.08 software to analyze the data [21]. In model 3, we put three task-level variables, close-landing demand, task-load of the provider, and task-load of the requestors, into the model. Job experience was also entered into the model as a control variable. Job experience was also entered into the model as a control variable.

The results showed that the close-landing demand (β = .711, p < .01), task-load (β = −.590, p < .01) and requestors workload (β = .147, p < .01) all significantly predicted the backup decision-making. Specifically, participants were more willing to accept the aircraft if it had a close-landing demand, when their task-load was low and when requestors' task load was high. Therefore, H1 to H3 were all confirmed.

In model 4, the perceived legitimacy and mental workload were added into the model. The results showed that perceived legitimacy was a significant predictor of backup decision-making (β = .426, p < .01), while mental workload had no significant influence (β = .194, *n.s.*). At the same time, the effects of the three task-level variables were all reduced. The task-load of the requestor was a drop from 0.147 to 0.059 (β = −.182, p < .01) which was no longer significantly predicted the backup decision-making. The close-landing demand (β = .545, p < .05) and the task-load of the provider (β = .377, $p < .01$) was still predicted backup decision-making, but the effects were weakened. The perceived legitimacy mediated the influence of all three task-level variables on backup decision-making. Therefore, H4 was not confirmed, but H5 was confirmed.

2.3 Discussion of Study 1

The results of Study 1 fully confirmed H1 to H3 suggesting the functions of the task-level variables were in agreement with our expectations. Also, it confirms H5 suggesting perceived legitimacy plays an important mediating role. However, H4 was not supported suggesting mental workload could neither predict backup willingness nor decision. One possible reason is that when making a decision of the future, it is not the current mental workload of controllers that matters. When deciding whether to accept a backup request that happens in the near future, the controllers may need to evaluate whether he/she will have available mental resource in that period rather than contemplating how he/she experienced in the past (what the mental workload variable measured in study 1). Literature in ATC decision making also pointed out the importance of making future anticipations, such as trajectories [12] or mental workload [26]. As a result, we suggested that it might be anticipated workload, rather than current mental workload, that would play the mediating role. Therefore, we modified H4a as:

H4a. *The anticipated mental workload of the participants is positively related to the possibility of backup behaviors in ATC.*

In order to replicate the major findings of study 1 and our modified new hypothesis, we conducted study 2.

3 Study 2

In study 2, we sought to make a replication of study and test our new hypothesis related to anticipated mental workload. In doing so, we used similar task configurations as compared to Study 1 but adding a new item measuring anticipated mental workload.

3.1 Participants

In total, 22 licensed professional ATCos participated in this experiment. Their ages ranged from 22 to 34 years (M = 26.50, SD = 3.14) and ATC experience ranged from 1 to 11 years (M = 4.18, SD = 2.99). Finally, all of the data were available for analysis. All participants were paid 150 RMB after completing this experiment. All participation was voluntarily and anonymously.

3.2 Method

All experimental settings were similar to Study 1, except for adding a new item to measure anticipated mental workload. This item was added before responding to the question about the perceived legitimacy of backup. Anticipated mental workload was measured by using an 8-point item "how much do you think it will bring you extra work if you accept the handover aircraft?" (1 representing very low and eight very high).

3.3 Results

Basic Analysis. Table 3 provides the means (M), standard deviations (SD) the correlations of all variables. From the table, we can see that both backup willingness and decisions were significantly correlated with the three task-level variables and the two mediating variables.

Table 3. Means, standard errors and zero-order correlations of all variables in study 2 (n = 22)

	M (SD)	1	2	3	4	5	6	7	8
1. Close-landing demand	.50 (.50)								
2. Task load of the provider	7.00 (3.00)	-							
3. Task load of the requestor	5.00 (3.00)	-	-						
4. Mental workload	2.24 (1.68)	.001	.60**	.02					
5. Anticipated mental workload	4.41 (2.90)	−.001	.80**	−.04	.65**				
6. Perceived legitimacy	3.47 (2.67)	.05	−.54**	.18**	−.37**	−.60**			
7. Backup willingness	3.71 (2.75)	.03	−.65**	.13**	−.48**	−.72**	.81**		
8. Backup decision	.47 (.50)	.06	−.70**	.08**	−.51**	−.76**	.62**	.75**	
9. Job experience	4.18 (2.99)	-	-	-	−.03	−.13	.02	.04	.07

Multilevel Regression Modeling. Similar to Study 1, we established the models by using backup willingness and backup behavior as the dependent variables. In the null models, the intra-class correlation (ICC) of backup willingness and backup behavior were 9.81% and 9.71%, respectively, suggesting the necessity to use the multilevel modeling approach.

Next, we entered Job experience and the three task-level variables, into the first step (model 1 and model 4). Similar to study 1, the result showed that all three task-level variables (close-landing demand, provider's task-load, and the requestor's task load) all had significant influences on participants' backup willingness and backup behavior (see Table 2 for details).

In the second step, the perceived legitimacy and the current mental workload were added into model 2 and model 5. Similar to study 1, the perceived legitimacy mediated the effect of task level variables on willingness ($\beta = .614$, $p < .01$) and backup behavior ($\beta = .503$, $p < .01$). Current mental workload, however, also had a significant influence over backup willingness ($\beta = -.177$, $p < .05$) and backup behavior ($\beta = -.238$, $p < .05$).

In the final step, the anticipated workload was added into model 3 and model 6. It was found that anticipated mental workload significantly predicted backup willingness ($\beta = -.275$, $p < .01$) and backup behavior ($\beta = -.411$, $p < .01$). Moreover, adding anticipated mental workload into the models significantly reduced the effects of current mental workload on the backup willingness ($\beta = -.114$, *n.s.*) and backup behavior ($\beta = -.124$, *n.s.*). Therefore, the anticipated mental workload was a more proximal predictor of back up behavior, which played the mediating role between task-level variables and backup behavior. Therefore, H4a was confirmed.

3.4 Discussion of Study 2

As did in study 1, Study 2 further confirmed H1 to H3 suggesting the three task-level variables were important predictors of backup willingness and decision. Also, perceived legitimacy was found to play the mediating role again. Moreover, study 2 also supports H4a, suggesting it is an anticipated mental workload that plays the mediating role in making a backup decision (Table 4).

Table 4. Hierarchical linear model in experiment 2

Parameter	Backup willingness			Backup decision (1 backup, 0 refuse)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	3.710** (.20)	3.710** (.20)	3.710** (.20)	.211 (.26)	.417 (.24)	.493 (.26)
Individual-level variable (N = 22)						
1. Job experience	.041 (.06)	.041 (.06)	.041 (.06)	.116 (.08)	.123 (.08)	.104 (.08)
Task-level variable (N = 704)						
2. Close-landing demand	.164 (.16)	−.026 (.07)	−.010 (.07)	.556* (.24)	.527* (.20)	.601* (.23)
3. Task load of provider	−.601** (.04)	−.242** (.06)	−.076* (.03)	−.615** (.05)	−.414** (.06)	−.198** (.05)
4. Task load of requestor	.125** (.03)	.026 (.02)	.023 (.01)	.108* (.05)	.026 (.03)	.020 (.02)
5. Perceived legitimacy		.614** (.07)	.556** (.08)		.503** (.08)	.465** (.09)
6. Current mental workload		−.177* (.08)	−.114 (.08)		−.238* (.11)	−.124 (.10)
7. Anticipated mental workload			−.275**(.07)			−.411** (.07)

notes: *p < .05, **p < .01

4 Overall Discussion

In our research, we attempted to explore the mechanisms underline the backup behaviors of ATCos from the viewpoint of backup providers. In testing our hypotheses, we conducted two studies by recruiting professional ATCos in performing a parallel runway operation task.

Across two studies, we found that task-load distribution was an important predictor of controllers' backup decision making: controllers are more likely to provide help when their own task-load is low and when their colleague's task-load is high. These results, fully confirming H1 and H2, are consistent with previous studies in general areas of cooperation [3, 39, 40]. This finding provides a new way to look at the critical issue of controllers' mental workload. Although overload may occur at some time for some controllers, as long as there are other underload controllers at the same time, backup behaviors can help adjust they workload distribution in increasing the overall performance of aviation efficiency and safety.

Besides, the close-landing demand was found to affect the willingness and final decision of backup. Specifically, if the aircraft had a close-landing demand, controllers are more likely to accept the hand-over of this kind of aircraft. Confirming H3, this factor was first identified in the literature of ATC and team backup behaviors. To note, although accepting aircraft with a close-landing demand can save the waiting time of the crew and passengers, it is neither required nor beneficial for the personal interests of the controllers. Indeed, such a kind of behavior can lead to extra effort on the side of the providers. As a result, this phenomenon can be seen as an altruistic and prosocial behavior that is beyond team cooperation. Future studies may take further steps to see other similar conditions that may contribute to controllers' backup behaviors, in the scope of organizational citizenship or customer service literature.

In addition, both studies found that perceived legitimacy played an important mediating role (H5). This finding corroborates previous theoretical argument that a legitimacy evaluation process is involved in making the backup decision making [3, 39, 40]. However, our study is the first to measure this construct empirically. Since there are still a large number of individual differences behind this perception, future studies may further explore how people form different legitimacy evaluation upon similar targets and situations.

One of the most interesting findings of the present study was that it was the anticipated mental workload in the future that plays a more important role in forging controllers' backup decision, as compared to their current mental workload. However, a lot of ATC researches mainly focus on the measurement and the function of the latter. According to our analysis, the future workload may have a greater influence on the controller's strategy choice and behaviors. This finding is inconsistent with some new progress in the domain of general decision-making [1, 4, 48] and some studies focusing on mental workload management in the area of ATC [26, 47]. Future studies may benefit from exploring the formation and function of this variable. For example, how to help controllers to form an accurate evaluation of their future workload? How to help them make better decisions using this information?

Before concluding, it is important to discuss some potential limitations of the study. First, this study only utilized a relatively small sized sample; however, this is a common practice for studies based on professional controllers and other similar occupational groups (e.g., [5, 17, 26, 30, 42, 46, 47, 50, 53]). However, we ensured the validity of the study by using two experiments to survey a repeated verification. This procedure, while minimizing the potential confounding variables such as interpersonal relationships and social ranking, can offer a better understanding of the task-level properties. Future studies may benefit from including more "social" variables into the exploration, such as familiarity and team personalities, which, however, requires the researchers to have a much larger pool of participant.

5 Conclusion

In this paper, we focused on the cross-sector backup and recruited professional controllers to conduct dynamic parallel final approach missions. We found that the ATCos were more likely to provide help to their colleagues if the request is made when their task load is low, when their colleagues' load is high and when the request can benefit the crew and passengers. Also, the effects of these variables were mediated by two psychological variables: the perceived legitimacy and the anticipation of future mental workload of the backup.

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