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Helicopter pilots' views of air traffic controller responsibilities: A mismatch

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Abstract

Controllers and pilots must work together to ensure safe and efficient helicopter flight within the London control zone. Subjective ratings of pilot perception of controller responsibility for five key flight tasks were obtained from thirty helicopter pilots. Three types of airspace were investigated. Results indicate that there is variation in pilot understanding of controller responsibility compared to the formal regulations that define controller responsibility. Significant differences in the perception of controller responsibility were found for the task of aircraft separation in class D airspace and along helicopter routes. Analysis of the patterns of response suggests that task type rather than the airspace type may be the key factor. Results are framed using the concept of a shared mental model. This research demonstrates that pilots flying in complex London airspace, have an expectation of controller responsibility for certain flight tasks, in certain airspace types that is not supported by aviation regulation.

Keywords

Transportation safety, shared mental model, helicopter, air traffic controller.

Practitioner Summary

The responsibility for tasks during flight varies according to the flight rules used and airspace type. Helicopter pilots may attribute responsibility to controllers for tasks when controllers have no responsibility as defined by regulation. This variation between pilot perceptions of controller responsibility could affect safety within the London control zone.

1. Introduction

Pilots and controllers are part of two operationally independent systems (Hoc and Debernard, 2002). Working as a team across this complex sociotechnical, system-of-systems the controller-pilot interface ensures the safe progress of flights (Harris and Stanton, 2010). A key dimension of a systems-of-systems is the definition and operation of the interface between the different systems (Siemieniuch and Sinclair, 2015). Pilots need to conduct defined tasks to ensure the safety of their system. System evolution, driven by a goal of an improved level of safety, has defined that from time-to-time, controllers assume responsibility for some of these pilot tasks. The transfer of responsibility for a task between the systems, across the interface is defined by aviation regulation, which is common, or shared between the pilot and controller systems. A shared understanding of who holds responsibility for each of the key tasks under the various combinations of task, airspace and flight rules types is essential for the safe and timely transition of responsibility of the tasks as the context changes. A task left unmonitored or incomplete can result in a degradation of safety.

Systems comprising more than one person have properties over and above those individuals making up the system and the various actors within the system may have common elements to their understanding which allows them to act in a co-ordinated manner (Dobbins et al, 2015). The pilot and controller systems are components of the wider aviation system. Salas et al (1992) defined a team as “two or more individuals, who have specific roles, perform interdependent tasks, are adaptable and share a common goal” A system can be viewed as a team comprising of interacting members forming an integrated whole (Jonker, et al., 2011). There is converging evidence that suggests that humans working in teams employ shared mental models to represent relevant information about the task. Although teams can be

considered as face-to-face groups, they can also be geographically distributed individuals communicating using phones, radios, and other devices as is the case in the aviation system (Scheutz, M., 2017). A shared mental model has been defined as '*knowledge structures held by team members that enable them to form accurate explanations and expectations for the task, and in turn, coordinate their actions and adapt their behaviour to the demands of the task and other team members*' (Cannon-Bowers et al., 1993). When team members can communicate and strategize freely, shared mental models may not be so critical to performance (Stout et al., 1999). The team members can discuss the next move and does not need to rely on pre-existing knowledge and understanding. Under conditions where communication is more difficult or restricted, shared mental models contribute to performance as they allow team members to predict the needs and behaviours of others in terms of shared expectations (Stout et al., 1999; Pritchett and Midkiff, 1995; Cannon-Bowers et al., 1993). In the aviation environment controllers and pilots do not tend to engage in free-speech because of the imposed highly procedural communication and the limited time available to each party. This constrained and procedural communication encourages, and we suggest demands, the use of shared mental models. A shared mental model can allow pilots and controllers to draw on their own pre-existing knowledge as a basis for predicting the behaviour of the other party and selecting actions that are consistent and coordinated (Mathieu et al., 2000; Marks et al., 2000). A shared mental model does not imply an identical mental model, but "*rather, the crucial implication of shared mental model theory is that team members hold compatible mental models that lead to common expectations for the task and team*" (Canon-Bowers et al., 1993).

In this research, we propose that the understanding of individual responsibilities at this interface is informed by a mental model (Carayon et al., 2015). We suggest that compatible mental models contribute to a shared mental model generating the common set of

expectations described by Cannon-Bowers et al. In this article we examine helicopter pilot understanding of controller responsibility across a range of tasks. Differences in understanding may affect helicopter pilot expectation, confounding the overall shared mental model to which we have alluded.

Key tasks are examined such as maintaining appropriate physical separation from the ground, other aircraft, and vertical obstructions such as telecommunication towers and tall buildings. The safety of the aircraft is also highly-influenced by the flight being conducted in appropriate weather conditions, and the application of the correct set of flight rules by the pilot, for the weather encountered. For example, in conditions of good visibility, the pilot will apply Visual Flight Rules (VFR), and in conditions of poor visibility, the pilot will apply Instrument Flight Rules (IFR). In the latter case, the pilot will fly with sole reference to the cockpit instrumentation.

We focus on London airspace defined as the inner and outer areas of the London Control Zone and the London City Control Zone. We use structured interviews employing scenarios presenting five key tasks in three different airspace types. Pilot expectation was compared against controller responsibility as defined by regulation. Differences are explained as variation in the mental-model of helicopter pilots.

2. Method

2.1 Design

The key tasks were identified from a review of aviation regulation conducted by the authors. Aircraft separation, terrain clearance, obstacle clearance, determination of the suitability of the weather, and selection of the flight rules were identified (Civil Aviation Authority, 2013; European Aviation Safety Agency, 2013). Table 1 summarises these formal responsibilities of pilots and controllers. From these tasks, the controller is only responsible for aircraft separation within Class A airspace, and aircraft separation for flights conducted under Special VFR.

[Table 1 near here]

Structured interviews were used to elicit pilot perception of controller responsibility. Participants were asked about controller responsibility across the three types of airspace for each of the five key tasks identified. Three helicopter flight profiles were developed to stimulate consideration of the specific types of airspace and associated procedures and rules. Five questions were developed to assess the magnitude of pilot expectation of controller level of responsibility for the tasks. Pilots were asked to rate the level of controller responsibility using a visual analogue scale (VAS) for each of the five tasks. Visual analogue scales comprise a continuous line with two or more labels. These labels are termed 'scale anchors' and a VAS must have at least two scale anchors at the ends of the line. Participants then mark a point on the line which aligns with their subjective view in the context of the question being asked. A distance measurement from one of the scale anchors or the mid-point can then be taken representing a value. For example, a typical Likert scale: strongly agree, agree etc. could be re-expressed as a VAS with the anchor points 'strongly agree' to 'strongly disagree'.

Measurement equivalence between the Likert and VAS formats has been demonstrated empirically by Kuhlman et al. (2017). Advantages of the VAS approach include greater granularity of response since many Likert scales measure across five or seven points. In addition, Likert scales do need to be *scaled.* The use of considered scale anchors increases the wide range of the constructs that can being measured and then reliably exposed to statistical procedures that demand interval level data (Reips and Funke, 2008).

2.2 Participants

The study was approved by the University ethics board and informed consent was given prior to participation. Thirty participants were recruited opportunistically by approaching helicopter companies and helicopter flying schools. A snowball sampling approach was used where participants recommended suitable acquaintances. Participants were required to be holders of a UK national or EASA helicopter commercial pilot or airline transport pilot licence. Participants were broadly divided in half by number of flights conducted. Fifteen participants had conducted 100 flights or more inside the London airspace within the last 10 years (median = 200, range 100 – 3000). Fifteen participants had conducted fewer than 100 flights inside London airspace within the last 10 years (median= 15, range = 1 - 69). Fourteen participants had held a twin-engine helicopter rating within the last 10 years. Fourteen participants had held an instrument rating within the last ten years whilst twelve participants held both a twin-engine and an instrument rating within the last 10 years.

2.3 Materials

Flight profiles were developed to anchor participants to specific scenarios. Industry standard flight charts and written descriptions of the flight profiles were generated and developed as scenario cards. The three flight profiles were a route along Helicopter Route ‘H3’ from

Bagshot Visual Reporting Point to Battersea Heliport using the standard route and heights, a transit of Class D airspace from north-to-south overhead London City Airport at one thousand feet, and a direct routing through Class D airspace from Brent Reservoir Visual Reporting Point to Battersea Heliport at the standard heights normally directed by Air Traffic Control. The five questions relating to the different tasks for each of the scenarios were developed comprising: *"Considering Flight Profile one [two, three], please indicate how much responsibility you expect the air traffic controller to have for (1) terrain separation; (2) obstacle separation; (3) aircraft separation from your aircraft; (4) determining the suitability of the weather; (5) determining the flight rules?".* A 150 mm Visual Analogue Scale (VAS) was presented to participants to record their subjective perception of responsibility. Four equally spaced text anchors were provided beneath the VAS representing: not at all responsible, somewhat responsible, mostly responsible, and completely responsible. A free text box under each VAS was provided to record participant comment if given.

2.4 Procedure

After giving informed consent, demographic data was collected. Participants then answered questions about reference sources used to determine who holds responsibility for the key tasks, before and during flight. Participants were then presented with answer booklet and a brief description of the developed flight profiles together with the scenario card. Participants were reminded that all flights were under VFR and that the participant could ask for any question to be repeated. For each participant, the five questions were repeated for each of the three types of airspace, and all fifteen questions were presented in a randomised order. The participants were asked to indicate their magnitude of expectation for controller responsibility for each task within each type of airspace by placing a mark on the VAS. Participants were then thanked for their participation and debriefed.

3. Results

3.1 Sources of reference used by pilots

The five most frequent sources of reference reported by the participants *before* a flight to obtain information about who is responsible for the key tasks include other pilots (17), aeronautical information publication (15), communication with air traffic control (10), air navigation order (4) and navigation charts (3). Participants reported four sources of information that they would use to obtain information about who was responsible for the key tasks *during* flight. Recall was reported as the most frequent (23) followed by asking the controller (17), navigation charts (6) and other, commercial publications (1). The data collected on the use of reference sources to define responsibility for the key tasks during flight by pilots indicates that recall and asking the controller are used frequently.

3.2 Perception of responsibility scores

Participant scores for expectation of controller responsibility range from zero (not at all responsible) to 15 (completely the responsible). The median level of expectation of controller responsibility is shown for each of the five tasks within each of the three types of airspace at Figure 1. Median levels of responsibility are shown by solid horizontal bars for each task within each type of airspace. The edge of the boxes shows the interquartile range and the whiskers show minimum and maximum values. Outliers (>1.5 × IQR) are shown as dashes. High variability and many outliers are observed across all data indicating variability of perception of controller responsibility. Aircraft separation within all types of airspace possessed the highest values of pilot expectation of controller responsibility, followed by determination of flight rules.

[Figure 1 near here]

Figure 1: Expectation of Controller Responsibility by Task and Airspace

Examination of the distribution of the data revealed departure from normality. Distributions were typically highly skewed towards each end of the scale. This is to be expected since the concept of controller responsibility is inherently bipolar. It would be surprising if normally distributed data were found since this would indicate a greater level of uncertainty amongst pilots as to whether the controller was or was not responsible. Kolmogorov-Smirnov tests support the visual inspections of the distribution and the theoretical position. Significant departures from normality were found in each condition. This characteristic of the data precludes the use of parametric inferential-statistics for analysis.

To answer the research hypothesis that there will be differences in the expectation of responsibility across task and airspace type, two different analyses were conducted. Firstly, significance testing was used to establish whether there were significant differences between the median responsibility score and the regulatory designation of responsibility allocated to each task and airspace combination. Secondly, multidimensional scaling (MDS) was used to understand the similarities and differences between responsibility judgements assigned to each task and airspace combination.

The median of each task-airspace combination was tested against a value indicating the expectation of full controller responsibility or no controller responsibility. Selection of this value is not straightforward. Since pilot expectation of responsibility was measured on a visual analogue scale of 0 to 15, it is tempting to test against a value of 0 or 15. However, this would produce a sharp-null hypothesis, increasing the probability of a Type I Error; a significant effect claimed when none exists. Secondly, linear scales are subject to central-

tendency bias and participants can demonstrate an unwillingness to record a response at the extremes of the scale (Foddy, 1993). In summary, a null-hypothesis using 0 or 15 as the test value may say more about participant use of the scale than the pattern of pilot expectation of controller responsibility. No data in literature is applicable in establishing the extent of this bias on this scale. In order to mitigate this bias, conservative test values at the 25th and 75th percentiles of the data were used to test the hypothesis. These values correspond to 3.75 and 11.25 on the 0 - 15 scale and require a more conservative result from a hypothesis test to evidence a statistically significant difference than the use of 0 or 15.

Visual inspection of the variation around the median indicated that the assumption of symmetric distribution around the median cannot be supported. A non-parametric one sample test Wilcoxon test was considered and subsequently rejected due to its restrictive assumption associated with a symmetric distribution of the median differences. A one-sample sign-test does not require symmetry around the median and was selected. The reduced set of assumptions used by the sign-test does reduce the statistical power available to detect small differences and therefore could be regarded as a highly conservative test of differences.

All variables were tested against a directional, one-tailed hypothesis using Minitab 17. The null hypothesis was aligned with the regulatory locus of responsibility for the task-airspace combination. Rejection of the null hypothesis indicates that the median value of the responsibility scores is at variance with the regulatory requirement. Aircraft separation in Class A airspace is the responsibility of the controller and so a test value of < 11.25 was used. All other task and airspace combinations used a test value of > 3.75. A Bonferroni correction was used to control the familywise error rate among the fifteen tests, holding α at the conventional 0.05. A new critical value of <0.003 was required to achieve significance.

Results of the one-sample sign test indicate significant differences in median of pilot expectation of controller responsibility for aircraft separation in Class D airspace and helicopter routes, see Table 2. This indicates that pilots tended to assign a greater level of responsibility to controllers than defined by the regulations. High variability is also notable in pilot expectation of controller responsibility for flight rule determination across all three types of airspace, as evidenced by the high number of responses away from the regulatory definition.

[Table 2 near here]

The high variability in responses across all tasks and airspace type warrants further analysis to understand the patterns of responses across different tasks and airspace types. Multi-dimensional Scaling (MDS) was used to understand the relationships between the patterns of pilot responses, presenting these patterns graphically. The PROXimity SCALing (PROXSCAL) algorithm available in IBM SPSS 22 was employed to understand relationships between the variables in common space (Lewis-Beck et al, 2017).
Figure 2 shows iterations from one to fourteen dimensions. Higher stress indicates greater difficulty in fitting the variables into common space of the related number of dimensions. Solutions using more than two-dimensions do not show a significant rise in stress and are straightforward to represent graphically. The procedure was re-run specifying two-dimensional common space. In MDS, dimensions need not be interpreted as latent or underlying variables. The purpose of this techniques to examine similar response patterns in the assignment of controller responsibility by the pilot for the five tasks within the three different types of airspace. Tentative interpretations of the dimensions are proposed.

[Figure 2 near here]

Figure 2: Normalised Raw Stress by Dimension

In the common space polar-plot at Figure 3, unfilled shapes represent Class A airspace, grey-filled represent Class D airspace and black-filled represent H-routes. Three groups of responses are evident in the common space plot. A group of weather suitability, terrain clearance and obstacle clearance tasks have similar patterns of response. Two further groups comprising aircraft separation tasks and flight-rule selection tasks are evident.

[Figure 3 near here]

Figure 3: Common Space Plot of Tasks for all Airspace Types

One interpretation of the dimensions is that the horizontal axis represents pilot expectation of controller responsibility. Higher expectation of controller responsibility is found to the right of the plot. The vertical axis represents a pilot expectation of shared responsibility to varying degrees between the pilot and the controller.

Weather suitability, terrain and obstacle clearance are grouped to the left-hand side of the vertical axis and close to the origin of the horizontal axis indicating that pilots have a lower expectation of controller responsibility and a lower expectation of shared responsibility. Interestingly, the task of determining weather suitability for H-routes moves towards a higher level of expectation for controller responsibility and a higher level of shared responsibility than the other tasks within this group. The task of aircraft separation within Class A airspace is defined in regulation as wholly the controller's responsibility and this is reflected in the high value of pilot expectation for controller responsibility displayed. The values for flight rule determination are grouped to the right of the vertical axis indicating that pilots have an

expectation of controller responsibility which is reflected in the controller ability to close airspace to flights conducted under VFR. However, the lower values of shared responsibility compared to aircraft separation indicate that pilots believe that the responsibility for the task lies within the domain of *their* system. Only the pilot is able to interpret the weather encountered and determine the appropriate flight rules.

4. Discussion

This research has revealed variation in helicopter pilot perception of controller responsibility inside the London and London City control zones. Results indicate that pilots assign responsibility to controllers for separation when flying in both Class D airspace and when in H-routes. Controllers have *no* responsibility for aircraft separation within Class D airspace. In H-routes, London airspace controllers frequently delegate the responsibility of aircraft separation to helicopter pilots under a locally developed procedure known as ‘deemed separation’. A high-level of variation in pilot expectation of controller responsibility was found for terrain and obstacle clearance, the determination of weather criteria, and the selection of flight rules across all three types of airspace. Aviation regulation defines that controllers have no responsibility for these three tasks. The results suggest that pilots have a level of expectation of controller responsibility for tasks when the controller is not required to have such responsibility, as defined by shared or common regulation. Any level of pilot expectation of controller responsibility beyond that defined in regulation could promote a mismatch between what tasks the pilot is expecting the controller to take responsibility for, and those tasks that the controller is responsible for. For example, one assumption held by pilots could be that a controller is closely monitoring the flight profile of the helicopter on radar when not required to do so and would then intervene in the event of an unsafe situation developing, for example anticipated loss of separation.

This interpretation is supported by the significant differences in the median of pilot expectation of controller responsibility for aircraft separation in class D airspace and H-routes. Pilots tended to assign a greater level of responsibility to controllers for aircraft separation than defined by the regulations, and that they perceive the task as a shared responsibility. This may be related to the location of expertise and the radar information with the controller. The blurring of responsibility could be an expectation that controllers continue to monitor VFR and Special VFR helicopter flights after initial radio contact and permission to enter the zones has been granted. Helicopter pilots within London airspace are warned by controllers if they deviate from their designated or agreed flight path, and sometimes pilots are reminded of large vertical obstacles and approach high-ground by controllers. It may be the case that pilots perceive the flight paths of their helicopters to be closely monitored on radar when they are not.

Regulation defines that pilots are responsible for the selection of flight rules within all three types of airspace. Although no significant differences in median expectation of responsibility were found, the relative values of the responses indicate that pilots hold an expectation that controllers have some responsibility for the selection of flight rules, and an expectation that this is a shared responsibility. However, controllers can be required to close airspace to VFR traffic in conditions of low visibility. This closing action by controllers could be interpreted as a weather and flight rule compatibility decisions similar to the judgement that pilots are required to make. These controller decisions may lead pilots to have expectation that controllers *do* influence the type of flight rules in use. Such controller decisions may lead pilots to have an expectation of controller responsibility for flight rule determination. It could be the case that allocation of responsibility, as defined by regulation or local practices for a

task is influencing the perception of responsibility for the same task within different types of airspace.

The MDS analysis indicates three groupings of response are present within the data. A grouping of response for weather suitability, terrain and obstacle clearance suggests that pilots deem themselves more responsible for these three key tasks. There is a correspondingly lower level of expectation of controller responsibility or shared responsibility for these tasks. Regulation defines that the controller is wholly responsible for aircraft separation within Class A airspace. The MDS analysis also shows a close grouping of responses for aircraft separation. Regulation defines that the controller has no responsibility for aircraft separation within Class D airspace and H-Routes but does have full responsibility within Class A airspace. These results could indicate that the location of responsibility with the controller for the same task within several types of airspace is affecting pilot expectation. The pilot could believe that controller access to a radar picture would elicit a level of responsibility from the controller when the controller has no formal responsibility. The variation discovered within pilot expectation of controller responsibility when no responsibility exists indicates that pilot mental models may not be an accurate representation of the aviation regulations. The research indicates that the attribution of controller responsibility is more strongly linked with task type than airspace type. This mismatch in the pilot mental model could affect the shared mental model across the systems.

One limitation of the research is that only the views of pilots have been solicited. To gain the fullest possible picture of the operation controllers need to be included in future research. This is especially the case if the shared mental model itself is to be formally evaluated. However, our results indicate that this is a valuable direction to explore to understand the

nature of the pilot-controller relationship. Another limitation of the research is a change to the classification of airspace within the London control zones since conducting this research Class A airspace is no longer in use for helicopters under VFR in London. However, the MDS analysis indicates that grouping is predominantly associated with task type and not airspace type. As such we assess our findings as having relevance in the current airspace configuration.

Our findings lend support for methods that seek to characterise and understand sociotechnical systems in greater detail (Waterson et al., 2015). At the very least, the findings further support for activities that bring the reference materials and professional learning for system actors: controllers and pilots, closer together to ensure to an improved collective understanding. The results of this study may evidence the migration of work away from the prescribed rules and regulations in response to a complex sociotechnical system which has been subject to change over time. Snook refers to this as an 'uncoupling of praxis' from rules and procedures (Snook, 2000). A pattern of working conditions between controllers and pilots has emerged which is different from that which is prescribed. This way of working may deliver resilience given the current operational landscape but any future change may render such deviation less safe. Joint-optimisation through increased collaboration at the training and procedural development intersection would improve system safety (Kleiner et al., 2015).

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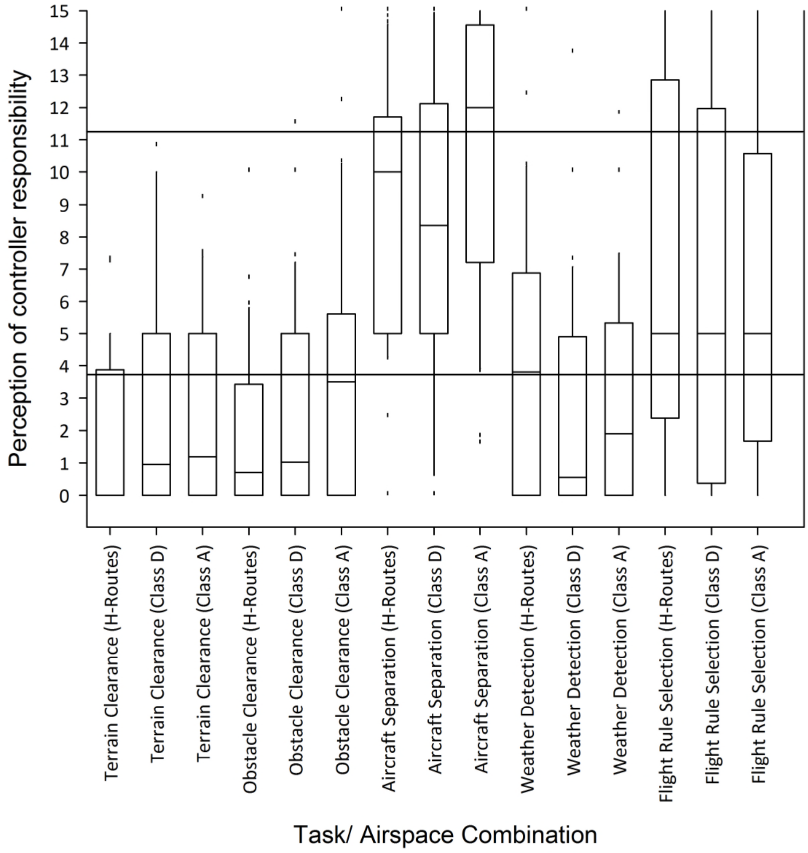
Key Task	Controller	Pilot
Aircraft separation in Class A	✓	✗
Aircraft separation for Special VFR Flight	✓	✗
Aircraft separation elsewhere	✗	✓
Terrain clearance	✗	✓
Obstacle clearance	✗	✓
Determination of the suitability of the weather	✗	✓
Determination of the suitability of the flight rules	✗	✓

Table 1: Allocation of responsibility for key tasks with *deemed separation* in use.

Airspace Type	Task	Hypothesised Direction	Cases in Hypothesised Direction	p (one-tailed)
H-Routes	Terrain Clearance	>3.75	7	> 0.990
	Obstacle Clearance	>3.75	7	> 0.990
	Aircraft Separation	**>3.75**	**28**	**< 0.003***
	Weather Suitability	>3.75	15	= 0.570
	Flight-Rule Selection	>3.75	17	= 0.292
Class D	Terrain Clearance	>3.75	8	> 0.990
	Obstacle Clearance	>3.75	10	> 0.990
	Aircraft Separation	**>3.75**	**25**	**< 0.003***
	Weather Suitability	>3.75	8	> 0.990
	Flight-Rule Selection	>3.75	16	= 0.428
Class A	Terrain Clearance	>3.75	9	> 0.990
	Obstacle Clearance	>3.75	15	= 0.570
	Aircraft Separation	<11.25	14	= 0.708
	Weather Suitability	>3.75	12	= 0.900
	Flight-Rule Selection	>3.75	16	= 0.428

Table 2: Sign-test of the median expectation of responsibility (n = 30)

*** indicates significant difference from hypothesised regulatory direction**



Perception of controller responsibility
15
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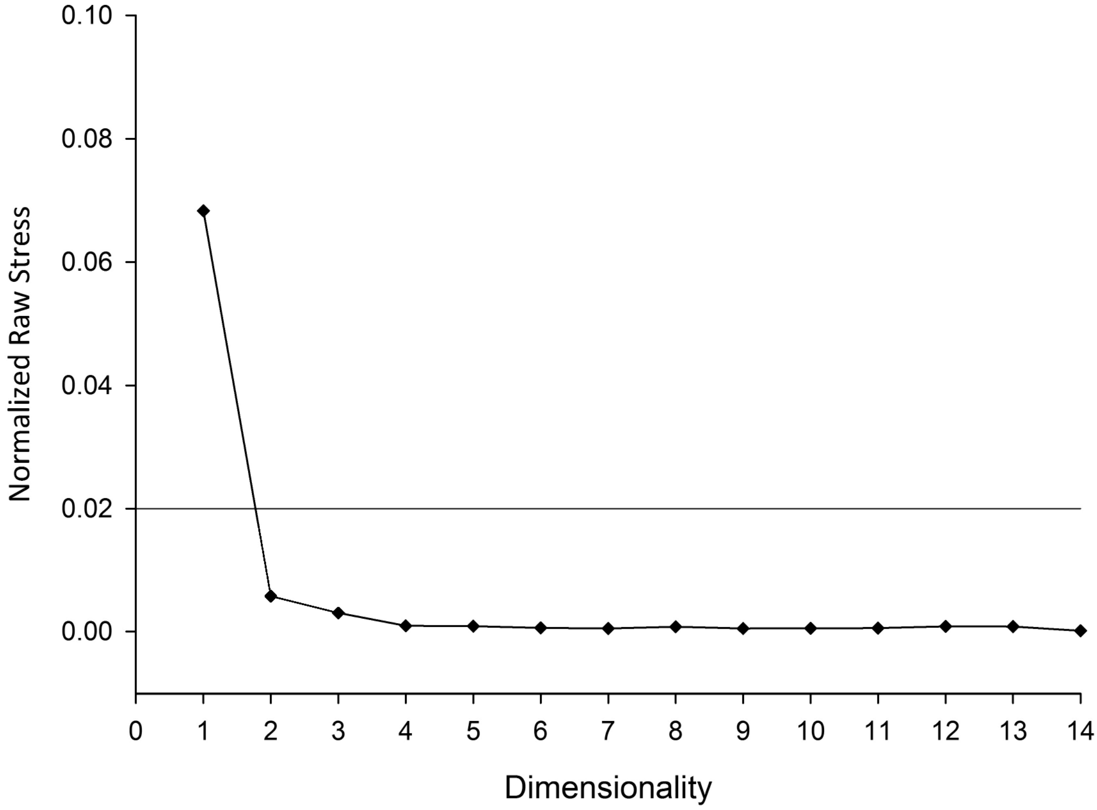
Terrain Clearance (H-Routes)
Terrain Clearance (Class D)
Terrain Clearance (Class A)
Obstacle Clearance (H-Routes)
Obstacle Clearance (Class D)
Obstacle Clearance (Class A)
Aircraft Separation (H-Routes)
Aircraft Separation (Class D)
Aircraft Separation (Class A)
Weather Detection (H-Routes)
Weather Detection (Class D)
Weather Detection (Class A)
Flight Rule Selection (H-Routes)
Flight Rule Selection (Class D)
Flight Rule Selection (Class A)
Task/ Airspace Combination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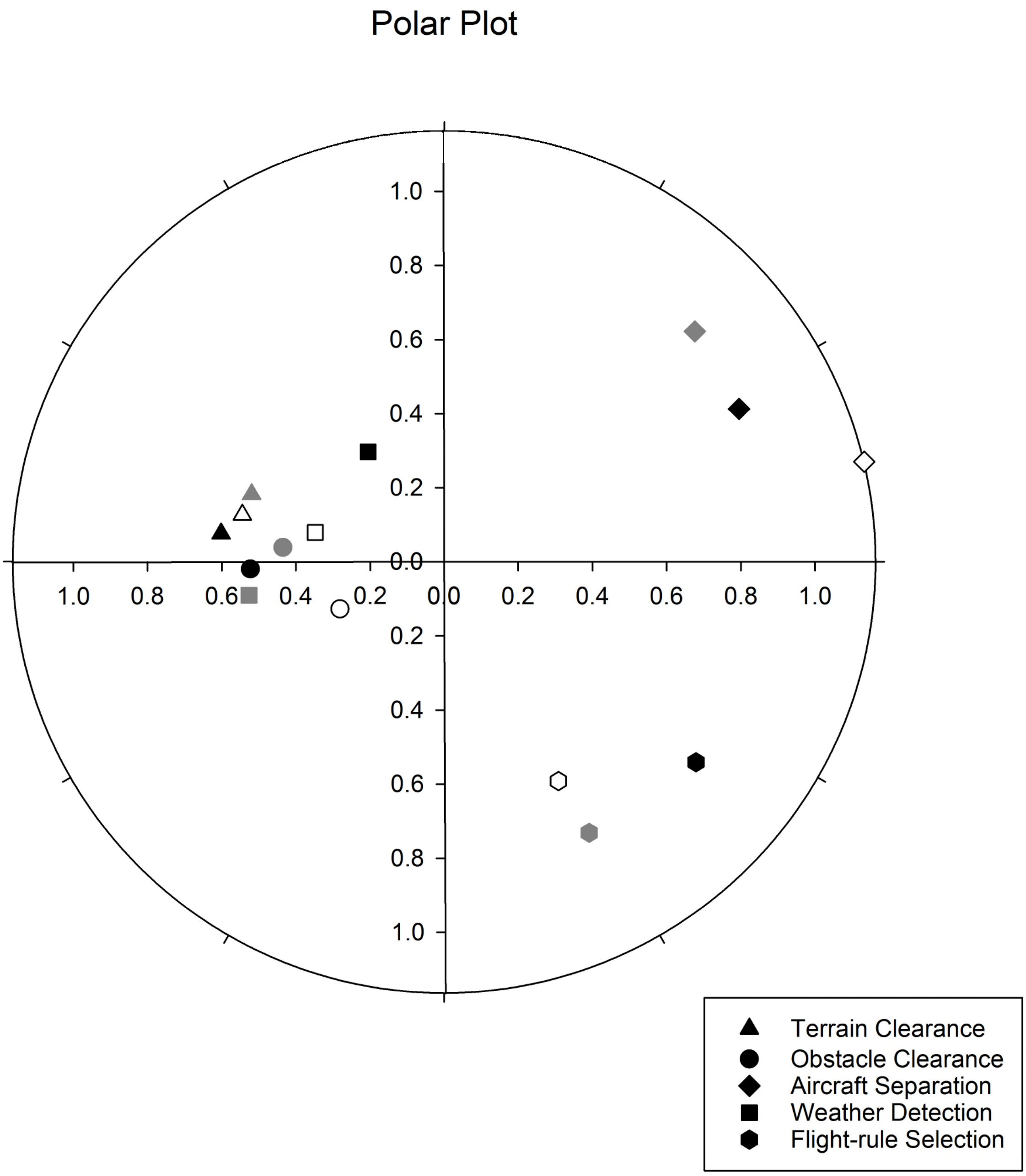
Polar Plot
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1.0
Terrain Clearance
Obstacle Clearance
Aircraft Separation
Weather Detection
Flight-rule Selection