Provocations

Provocation: Is the UAV Control Ratio the Right Question?

BY P. A. HANCOCK, M. MOULOUA, R. GILSON, J. SZALMA, & T. ORON-GILAD

There are a variety of ongoing attempts to generate unmanned aerial vehicle (UAV) technologies to exploit the advantages that these semiautomated and automated airborne platforms promise to render. (Although we refer specifically to *UAVs* here, our arguments apply, in principle, to all remote vehicles whatever their medium of operation. The principles themselves also extend to other forms of nontransport-based entities.) With regard to such operations, the collective community is searching for the ratio between operator(s) and vehicle(s) that will prove most efficient and effective.

At present, the estimates of this ratio vary widely around unity, where unity is a ratio of 1:1, UAV:operator. Current operational systems require a whole team of human supporters to launch, control, direct, recover, and maintain even one single UAV. Despite these difficulties, design aspirations are for ratios that significantly exceed unity, perhaps to near-term goals of 4:1 up to "blue sky" representations of perhaps hundreds of UAVs to a single operator.

Theoretically, one can continue to push for ever greater numbers of UAVs per operator. The functional design questions that follow are (a) should researchers and designers continue to strive for this ever higher ratio, and, (b) if they decide to go forward in this direction, what is the modal number? As with all design questions, the immediate answer is simple: It depends. However, in this article, we discuss whether in reality this is the appropriate question to pose.

The context of this question cannot remain totally unbound, so here we argue the case with regard to the dismounted infantry soldier. For an individual who is involved primarily in close combat conditions, human-centered design principles support the simple alternative – that the ratio is either one or none. It is this provocative assertion we wish to examine.

Intermittent and Remote Control

UAVs fit the basic definition of a robot: They are multifunctional, reprogrammable machines. The primary purpose of a UAV (compared with an unmanned combat aerial vehicle [UCAV], for example) is to gather information from remote locations and then to communicate the information primarily (or, at the least, partially) to the controlling individual. In this sense, control implies command authority, but this does not necessitate constant tracking activity. This form of intermittent control is characterized by a supervisory role with periodic, discrete commands as envisaged in the research of those such as Sheridan, Parasuraman, and others (see, e.g., Parasuraman & Mouloua, 1996).

In theory, under such a regimen, the number of controllable UAVs is directly contingent on the temporal capacity of each machine for independent, autonomous action (Mouloua, Gilson, & Hancock, 2003). For example, some UAVs, such as space-based satellites, need very few and very rare control inputs. Indeed, if the vehicle has 100% independence at all times, the number of controllable vehicles is prospectively without limit. Depending on the critical stability of the dynamics of the vehicle, if complete hands-on human control were needed at all times, the vehicle:operator ratio would certainly be at unity or below, as is evident with the control of inherently unstable flight platforms, such as helicopters.

Our problem, which is twofold, lies between these extremes. In essence, the question reverts to one of appropriate function allocation policy, a question that has persisted in human factors and human-centered design throughout its history (see Hancock & Scallen, 1996). For the purpose of argument here, we assume a high degree of independent capacity, leaving only the direction of higher-order goals (e.g., "Go here") as the residual human function. As a first-pass, time-and-motion description, this appears to leave significant "spare" capacity for the operator to perform his or her UAV tasks – and any other duties associated with the current mission. However, not all tasks and contexts are equivalent. For that reason, one must consider the critical, imperative nature of the dismounted infantry soldier's mission.

For an infantry soldier involved in ground combat, the primary concerns are survival and success, in that order. Soldiers engaged in combat have little time or attention to pay to UAV input because under these conditions, a distracted soldier is likely to be a dead soldier. This imperative seems to mandate a companion to the front-line UAV operator who guards him/her against any immediate or surrounding threats. More formally, the increase in distal situation awareness (SA) can be accompanied by a potentially very dangerous loss of local SA.

As a nonweapon delivery system, a contemporary UAV acts as an "eye in the sky." As one modern expression of technology, the UAV is actually a distal extension of the infantry soldier's visual system. As such, the design imperative is to generate a system consistent with – not in conflict with – human visual capacities. One basic, fundamental characteristic of the visual system is that, with some extremely minor exceptions, it treats the

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world as being approached from a unitary "eye point." When attempts are made, as has been done via technology, to displace the eyes in space in order to assimilate multiple viewpoints simultaneously, it threatens to generate significant operator confusion. This typically leads to disorientation and degraded operational capacity. It is true that with the functional plasticity of the human brain, one can train individuals to reconcile these initially incompatible visual perspectives, though not without potentially deleterious aftereffects.

Without this artificial integration, at best, multiple UAVs provide the soldier the opportunity to sequentially search areas of concern from multiple eye points – the equivalent of cycling through multiple camera views, as is, for example, evident in current building security systems. The issuance of high-level orders (e.g., "Go here") with concomitantly long neglect times already creates a problematic separation of perception and action that can lead to spatiotemporal distortion or disturbance to SA.

However, the critical design question is, why do we want ever more UAVs per operator? After all, the end of this process may well be a counterproductive situation in which UAV control itself demands the majority of operator attention and not the achievement of primary mission goals. It is a case of the tool driving the work, which is simply the wrong way around. Consequently, the superordinate design requirement is getting the right information to the right person at the right time.

Further, there is only a small and finite region of space over which the infantry soldiers themselves *need* to receive information. Their personal theater of operations is rather restricted. Coverage of wider battlefield spaces might well be better accomplished by remote personnel each accessing his or her own remote platform. Clearly, unmanned vehicles (UVs) at this level are only one component of a whole suite of vehicles (both manned and unmanned) that seek to facilitate theaterwide mission objectives. As one recedes farther from the physical point of conflict, the operator can afford to separate perception and action, such that high-level integration of information is most relevant at the command level. At this level of tactical decision making, it may be appropriate to persist in questioning the utility of multiple UAVs. However, here again, we find it difficult to foresee a commander not working in conjunction with all his/her support personnel.

Given the current nature of asymmetric warfare and expectations for future combat environments, the proximal configuration for the dismounted soldier is having either one UAV or none at all. Aspirations for greater capacity are always laudable, but from a resource viewpoint, we are not short of personnel per se. However at present, the 1:1 ratio seems preferable. Of course, soldiers will still take advantage of fully autonomous UAV output (after all, what is GPS for, anyway?). But the pressure to achieve an ever-greater personal ratio is destined for sensory input conflict, central decision-processing overload, and response confusion and interference.

To be sure, the human being as the ultimate adaptive system may be able to demonstrate multiple UAV control, but again, we consider this an instance of what design can do, not what design *should* do. Further, given that under most conditions, most individuals predominantly satisfice and not optimize, the present observation suggests that UAV neglect will get worse as the ratio grows.

Toward Systemwide Solutions

Although we have expressed our polemical assertion for the purpose of provoking discussion, we readily acknowledge that this rapidly evolving area is driven by many emerging technological innovations. It may well be that imminent advances in automation will render much of this discussion moot. Our expectation is that a systemwide perspective will be much more oriented toward information distribution than it will the individual human-machine partnerships that are used as primary sources.

In actuality, infantry soldiers rarely act in isolation. They are part of a group or a team that is itself a component of an ever-greater whole. In and among these other entities reside numerous technologies to assimilate, compile, and distribute information to support decisions. There is also a literal arsenal of capabilities to effect action. Swirling around this network of person-machine linkages are dynamic variations in demand (expressed at all levels of the system). Fluctuation in load and demand should never be allowed to encounter a bottleneck if it is possible to dynamically reallocate the load. The individual operator is therefore the appropriate unit of analysis only when such bottlenecks occur at that level. More generally, if one views the collective team as an integrated, flexible system, then the very question of the UAV:operator ratio may itself become essentially irrelevant.

References

Hancock, P. A., & Scallen, S. F. (1996). The future of function allocation. *Ergonomics in Design, 4*(4), 24–29.

Mouloua, M., Gilson, R., & Hancock, P. A. (2003). Designing controls for future unmanned aerial vehicles. *Ergonomics in Design, 11*(4), 6–11.

Parasuraman, R., & Mouloua, M. (Eds). (1996). *Automation and human performance: Theory and applications.* Mahwah, NJ: Erlbaum.

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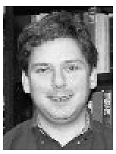

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Response: Is the "Is the UAV Control the Right Question?" the Right Answer?

BY J. W. SENDERS

I find myself unsure as to whether Hancock et al. are primarily discussing soldiers with individual control of one or more UAVs or a single controller handling many UAVs as eyes in the sky for individual soldiers. Why might there be "multiple eye points" other than by the unlikely use of more than one UAV for each soldier? A reasonable expectation is that a remote operator would control multiple UAVs, and the displays of information to the individual soldiers would be appropriately chosen and set by each of them.

The authors say, "When one attempts, as has been done via technology, to displace the eyes in space in order to assimilate multiple viewpoints simultaneously, one generates significant operator confusion. This typically leads to disorientation and degraded operational capacity." That sounds reasonable with respect to simultaneous viewpoints, but I am surprised that anyone would try it.

Do the authors mean actual simultaneous presence before the eyes of the user, or selection of viewpoints one at a time from a large set? If the latter, it all depends on how you do it. Wang's work (2004) suggests that varying tether length and eye location allows adjustment to optimality for local or global situational awareness. I see no major technical problem in allowing the local infantry soldier to adjust as needed the optical gain and virtual eye position of the information display while a remote UAV operator controls the location, orientation, and movement of the UAV.

Hancock et al. say, "Depending on the critical stability of the dynamics of the vehicle, if complete hands-on human control were needed at all times, the vehicle: operator ratio would certainly be at unity or below, as is evident with control of inherently unstable flight platforms such as helicopters."

However, even in this situation, with appropriate control and display systems, the handling of more than one machine remains both useful and practical. Simultaneous (actually, appropriately sampled) control of many high-order systems by one operator was demonstrated to be feasible when the displays of attitude (or whatever) are appropriately quickened. Henry P. Birmingham (still alive and well!) demonstrated this many decades ago by showing excellent simultaneous control of 2 two-dimensional, third-order systems (two submarines in depth and heading; see Birmingham, Kahn, & Taylor, 1954). Perhaps this is being used for UAVs and I am simply ignorant of it.

Even modestly intelligent design (admittedly, most designs have much to be modest about!) would allow multiple UAVs and multiple displays to be searched or monitored efficiently with good connectivity between the displays.

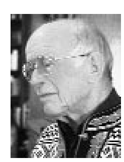
The authors' closing paragraph is unexceptionable: "The individual operator is therefore the appropriate unit of analysis only when such bottlenecks occur at that level. More generally, if one views the collective team as an integrated, flexible system, then the very question of the UAV:operator ratio itself becomes irrelevant."

I could not agree more.

References

Birmingham, H. P., Kahn, H., & Taylor, F. V. (1954, June). *A demonstration of the effects of quickening in multiple-coordinate control tasks* (NRL Report 4380). Washington, DC: U.S. Naval Research Lab.

Wang, W. (2004). *Human navigation performance using 6 DOF dynamic viewpoint tethering in virtual environments.* Ph.D. dissertation, University of Toronto, Ontario, Canada.



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