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Edgar, Graham K ORCID logoORCID: https://orcid.org/0000-0003-4302-7169, Smith, A J, Stone, H E, Beetham, D L and Pritchard, C (2000) QUASA: Quantifying and analysing situational awareness. In: IMCD People in Digitized Command and Control Symposium, 2000, RMCS Shrivenham, UK.

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Edgar, G. K., Smith, A. J., Stone, H. E., Beetham, D. L., & Pritchard, C. (2000). *QUASA: QUantifying and Analysing Situational Awareness. Paper presented at the IMCD People in Digitized Command and Control Symposium, RMCS Shrivenham, UK.*

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QUASA

QUantifying and Analysing Situational Awareness

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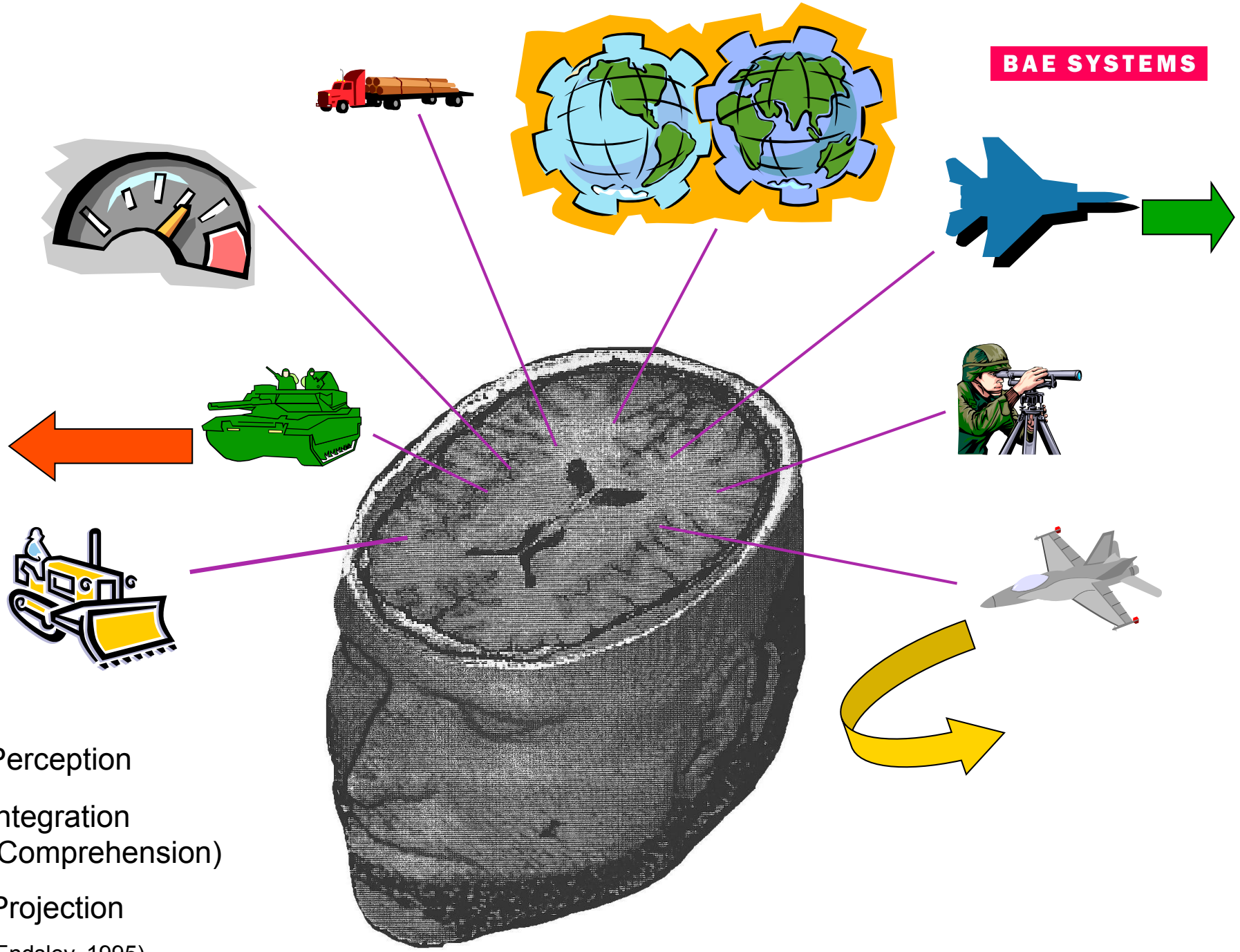
First assumption of QUASA tool:

A person's situational awareness is maintained within the head -i.e. within the brain (in memory).

This is my (Graham Edgar's) head.

The lack of hair and the weird beard are artefacts of the functional magnetic resonance image (fMRI) scanner that was used to obtain this image.



Perception

Integration
(Comprehension)

Projection

(Endsley, 1995)

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This is my head with the top sawn off.

Second QUASA assumption:

SA in any particular situation can be broken down into components. These may correspond to the aspects of SA given in the slide. These are the components proposed by Endsley (1995) although the term 'integration' is used here in place of Endsley's comprehension term - as it better represents the possibility that a person may have an awareness of the *wrong* situation - which QUASA can measure. Thus, the components of SA considered here are:
Perception: Having a knowledge of current facts and data - e.g. where specific units are. Basically sensory data.
Integration: Drawing information together to get the 'big picture'
Projection: Working out what will happen in the future.

The method of assessing these different components of SA using the QUASA tool will be considered later (Also see the paper in this conference by McGuinness and Foy for a complementary method) .

Reference

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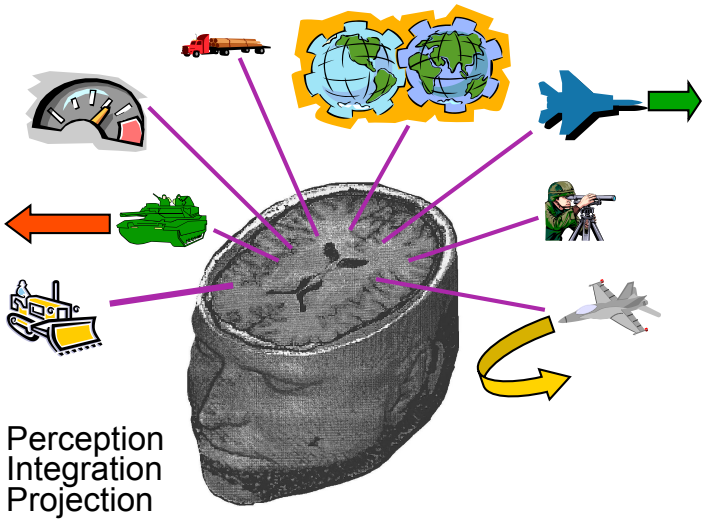
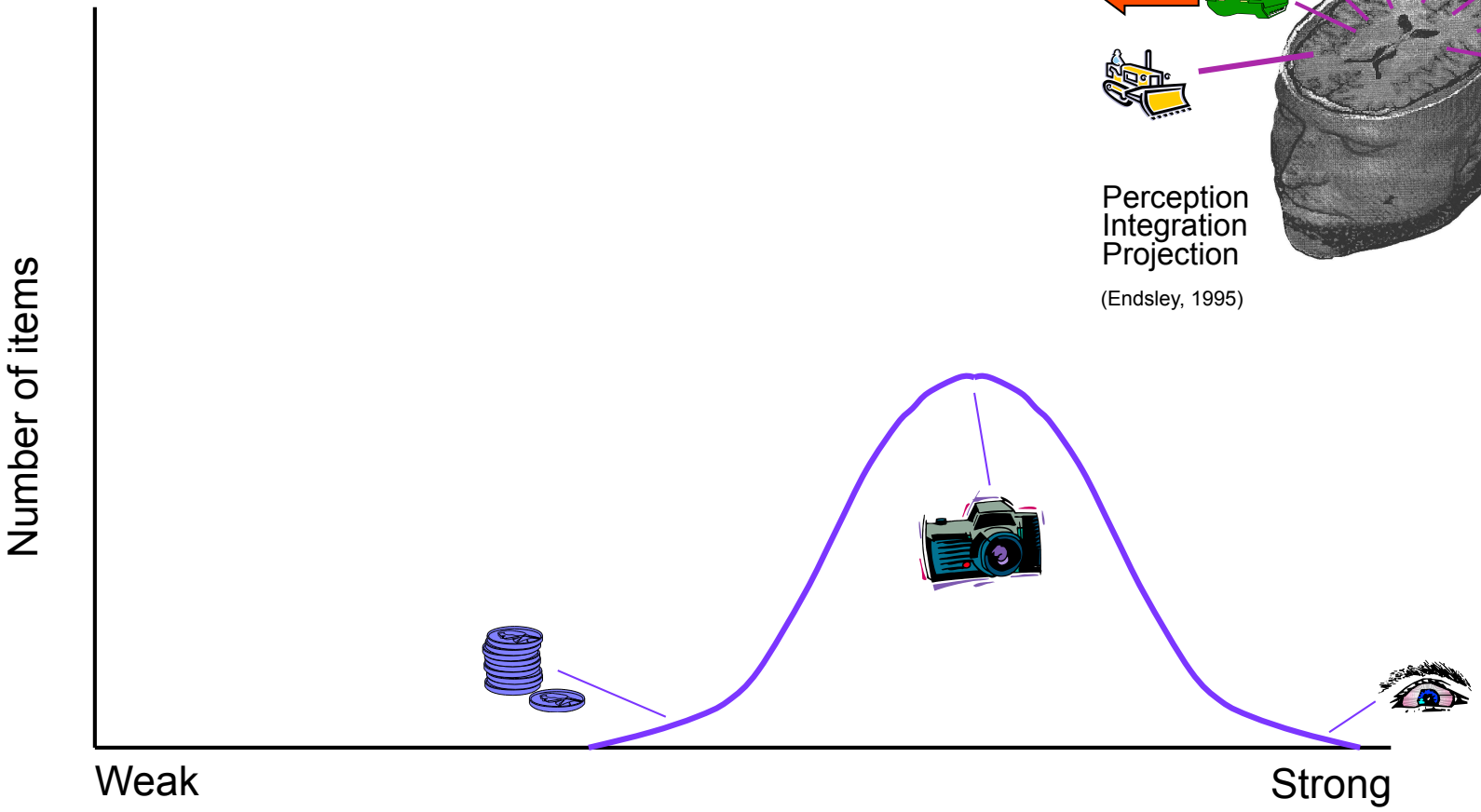


Perception
Integration
Projection

(Endsley, 1995)



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Third QUASA assumption:

The internal representation of a situation in memory is not ‘all or nothing’. Consider the curve in the diagram. This represents the possibility that representations of different parts of the situation may have stronger or weaker memory traces associated with them.
For instance, if you are looking directly at (and attending to) something then you probably have a very strong representation of that item and you can be pretty certain that it really is part of the situation - so that would place that item at the far left of the curve.
If however you are considering e.g. where your camera is at a particular moment - you may have a pretty good idea but not be *absolutely* certain that that is really where it is. Therefore the ‘strength’ associated with that particular item would be lower than something you are looking at (unless, of course, you happen to be looking at your camera!).
Finally, consider how much money you have - in coins. You may have a very vague idea - but it’s probably unlikely you know the exact amount with any degree of certainty. The internal representation of that item (amount of money) is therefore relatively weak - and so is at the left-hand end of the curve.
Thus the internal representations of some aspects of a given situation are very strong, some very weak - and most are probably somewhere in between. This is illustrated by the shape of the curve in the above figure. The curve has been plotted to suggest that most items have an intermediate strength. It does not matter for the QUASA tool if this is not the case.

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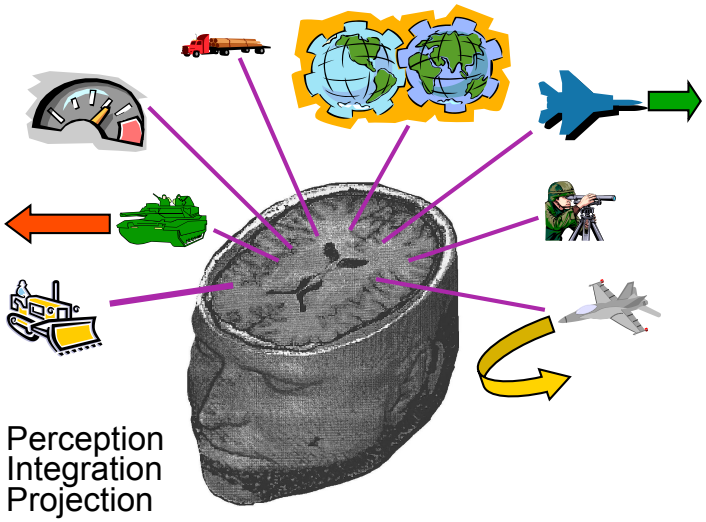
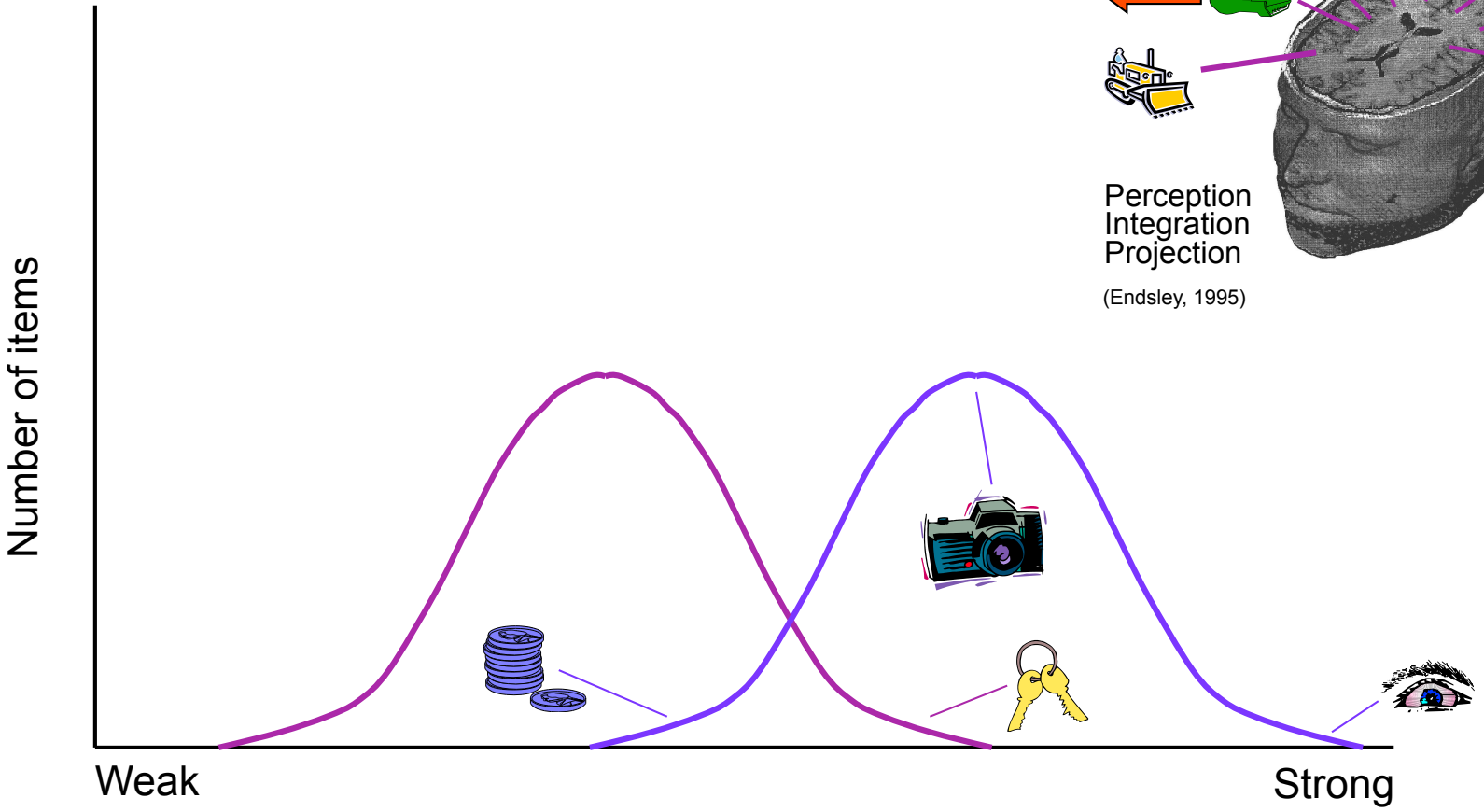


Perception
Integration
Projection

(Endsley, 1995)



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Fourth QUASA assumption:

Not just ‘true’ information is represented in memory. False information may also be stored. This may be due to misunderstanding or misperception of incoming information - or merely that the situation has changed without the individual realising it (so that they have a representation of ‘old’ information). I.e. SA is often less than perfect

Fifth QUASA assumption:

The false (untrue) information (represented by the left hand curve) will also have a range of ‘representation strengths’. Generally, the false information will have a weaker representation than the true items but they may well overlap with the ‘true’ situation.
For instance consider hunting for something (e.g. car keys). Most people will have had the feeling that they really *know* where a lost item is - to the extent that they can actually *picture* the item in that position. Yet when they go to that location to find the item - it is not there. This is an example of a piece of false information that nonetheless has a very *strong* internal representation.
N.B. it is possible for the distributions to be reversed (I.e. false info to have stronger traces than true information). The QUASA tool can accommodate this.

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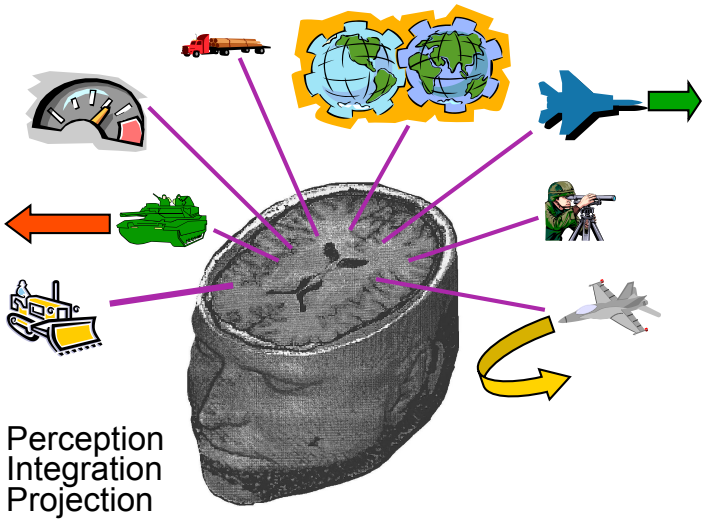

Perception
Integration
Projection

(Endsley, 1995)

SA’

Number of items

Weak

Strong

Strength of internal representation
of item (familiarity)

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SA according to QUASA

The definition of SA used by QUASA is a person's ability to discriminate between information drawn from the true and false representations of the situation. In the case above, even the strongest false items have a weaker representation than the weakest true items. The situation above represents the basis for very good SA.

I.e. if a person has very good SA then they will have a very strong representation of the true situation and a very weak (or even non-existent) representation of any false information).

N.B. *Lack* of information will also make it difficult to tell these distributions apart.

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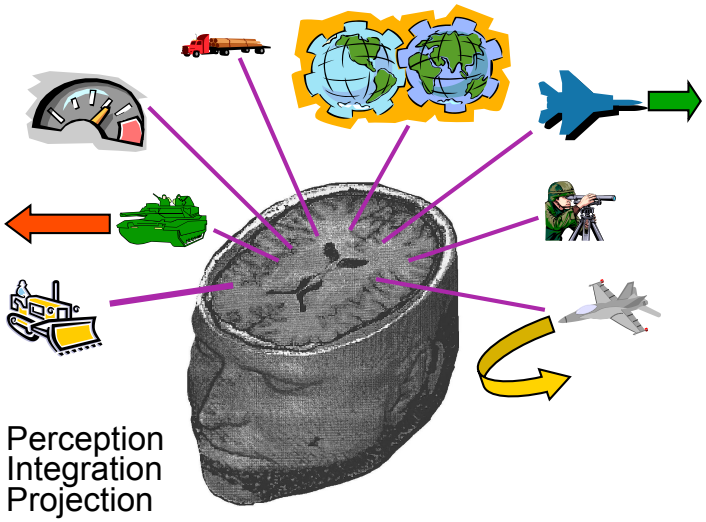
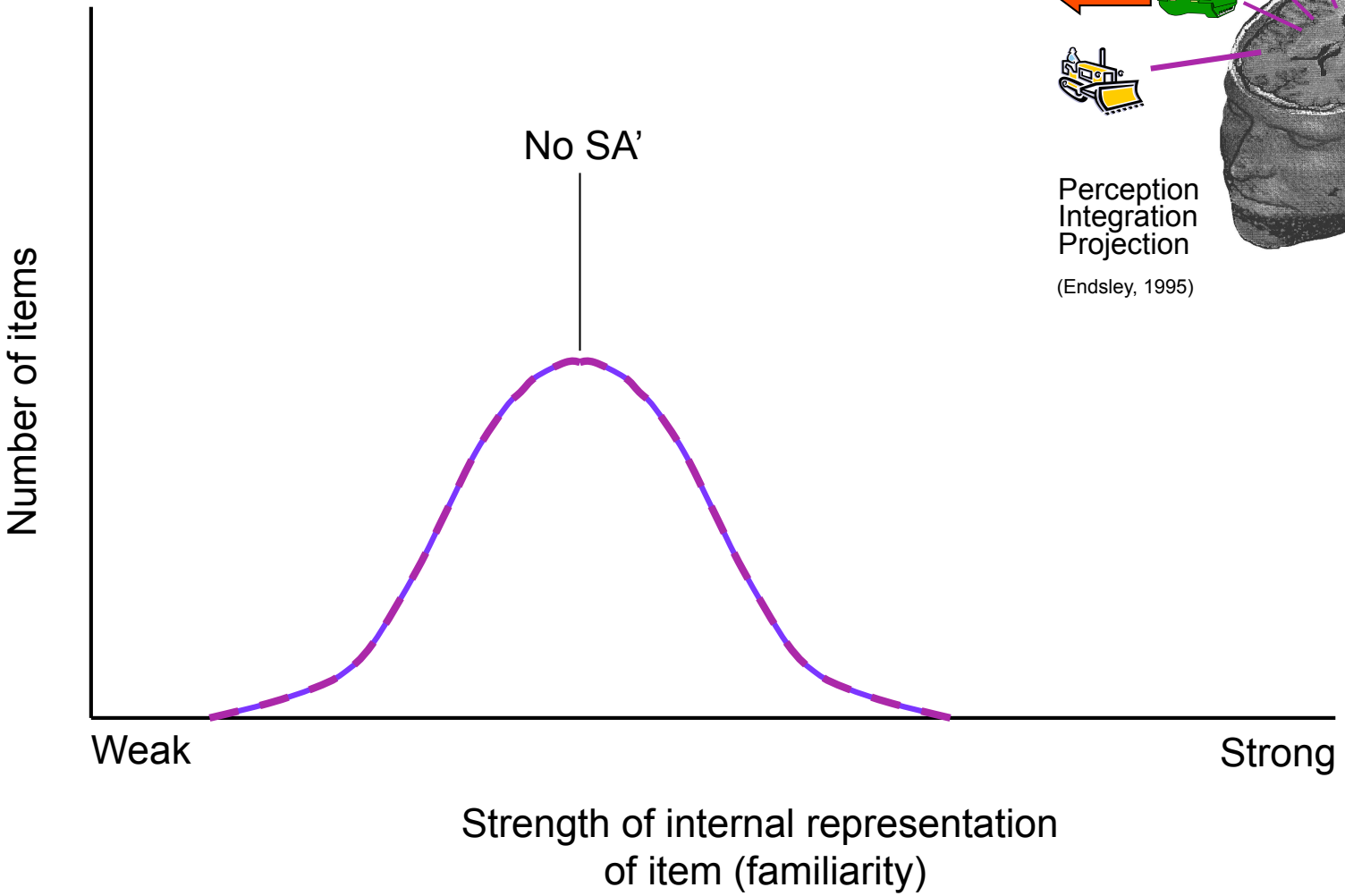


Perception
Integration
Projection

(Endsley, 1995)



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The situation in this slide represents an individual who has an equal number of items of the same strength that are true *and* false. I.e. the person cannot tell, just by considering the strength of the internal representation, which piece of information is true - and which is false. This is obviously going to make it very difficult for the person to judge what information makes up the true situation - and so represents very poor SA.

Thus, the distribution of true and false information represents a person's underlying SA. How 'good' or 'bad' this SA is will depend on how much confusion there is between the true and false information (I.e. how easy it is to discriminate between the two). The underlying SA will essentially be influenced by the *quality* of the incoming information - how reliable it is, how much of it there is and, crucially, the individuals correct interpretation of the information. I.e. if the quality of the information coming in is very high it will be much easier for the individual to tell if it is true.

So, good SA as represented in the previous figure, reflects successful collection and assimilation of incoming information - from whatever source (direct view of aspects of the situation, displays, communications from others, etc). There is, however, another aspect to SA which QUASA also assesses - and this is how the individual actually *uses* the information. The fact that true and false information may both be represented means that the individual is very unlikely to know, with absolute certainty, what is true and what is false. The individual therefore has to make a decision as to which information should be accepted as true - and which should be rejected as false - i.e. they have to decide how much confidence they have in the information at their disposal. Relating this to the true and false distributions we have been discussing so far…...

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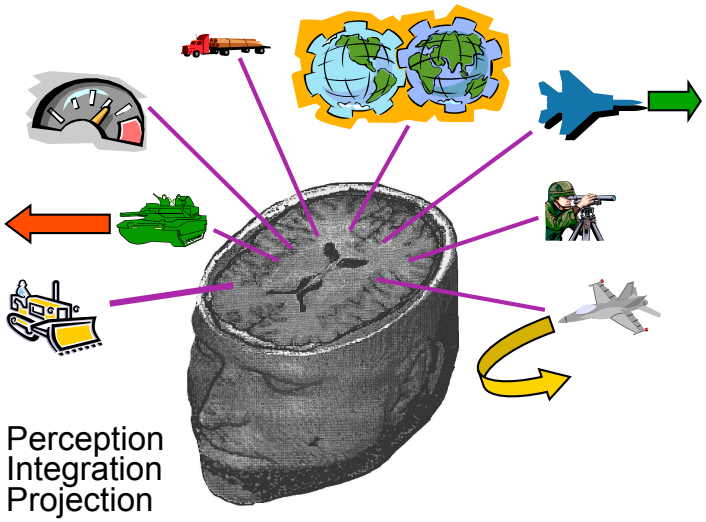
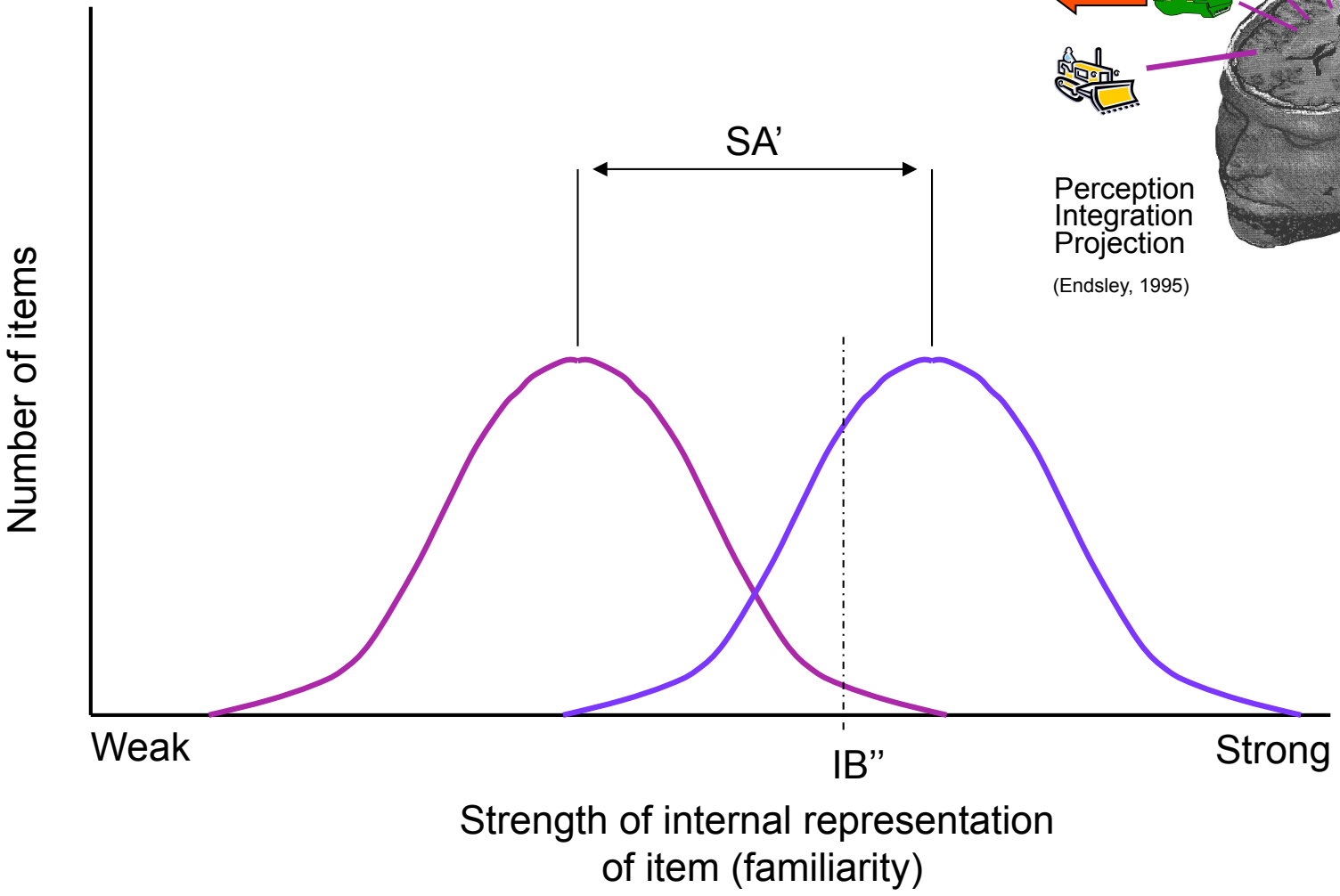


Perception
Integration
Projection

(Endsley, 1995)



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Sixth QUASA assumption:

An individual cannot conveniently ‘see’ the curves shown above for his/her own SA. They can only access the memory strength of a particular item - they have no way of knowing whether it is true or false. I.e. they may be more or less certain that an item is true (or find it easy or difficult to recall).
Thus, the individual must decide *how strong* an internal representation has to be to be accepted as ‘true’. This represents a bias (represented by the line IB’’) in the diagram. Essentially this means that the individual will accept items with strengths to the right of the line (I.e. ‘stronger’ traces) as true - and those to the left as untrue. This is completely independent of whether the items are actually true or not. This bias can change independently of the actual strength of the memory representation.
If, as shown here, the bias is towards the right (only strong memory traces accepted) the individual will accept little or no false information as true - but will also reject some true information. If the bias is to the left the converse is true. Centred between the two distributions is probably the optimum bias level - but this could vary according to actual situation.

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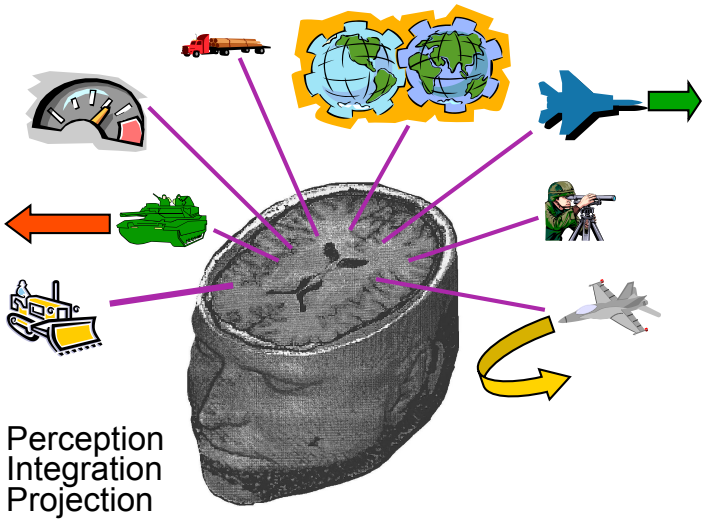
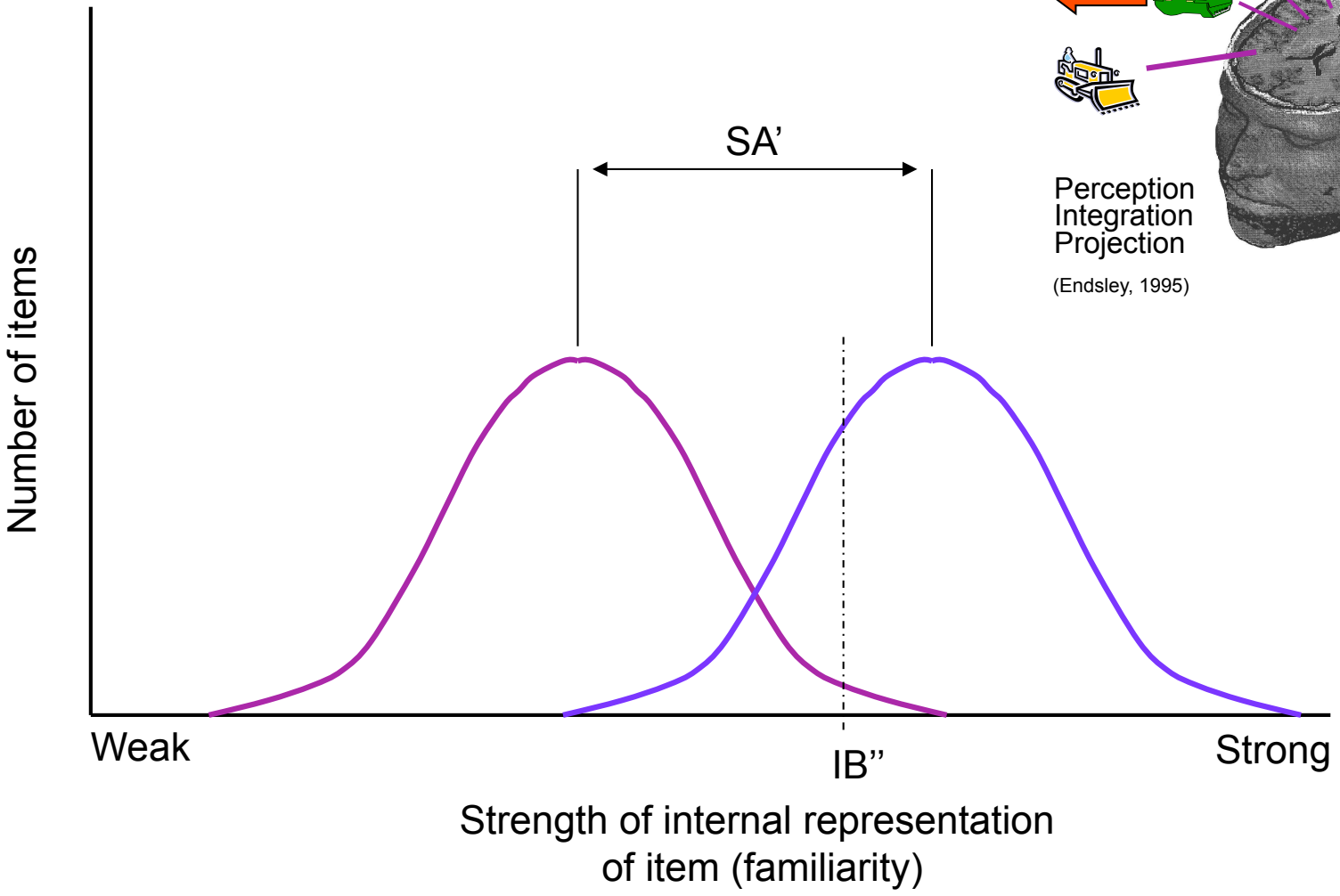


Perception
Integration
Projection

(Endsley, 1995)



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Sixth QUASA assumption (cont):

For instance, consider an individual looking at a particularly poisonous-looking mushroom. They would have to be pretty certain that their recollection of it being safe to eat was true before eating it. Thus they would only accept the internal representation of 'this mushroom is safe to eat' as true if the representation was *very* strong - because the consequences of a mistake could be serious.
It's important to note that the underlying representations of information (and thus actual SA) need *not* change - only the way the individual *uses* that information.

As stated, bias thus represents the way in which the individual makes use of the information at their disposal. This is most likely to be affected by the individuals *attitude* to the incoming information (level of confidence etc) and this is most likely to be influenced by an individual's disposition, experience, training, etc.

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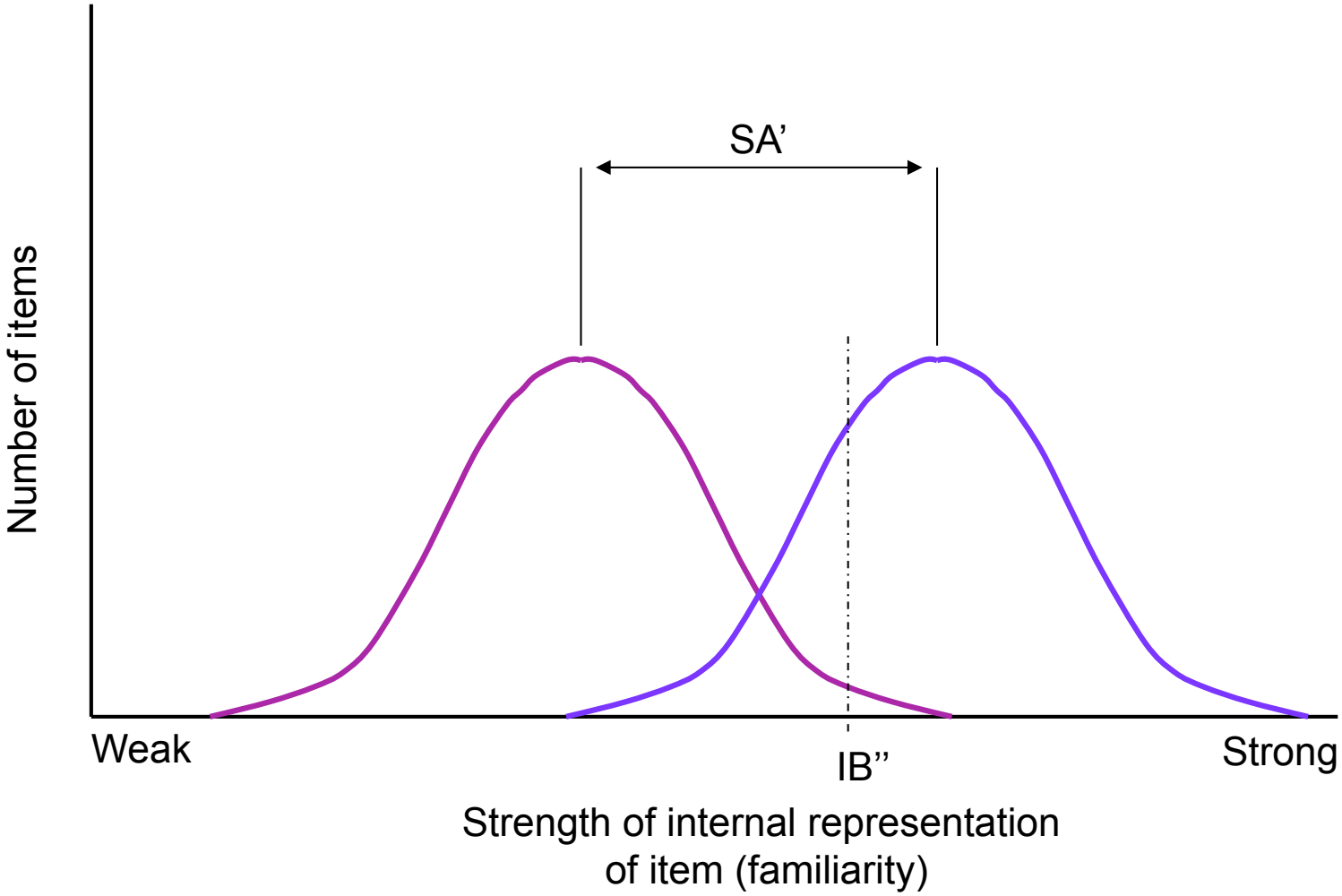
		Response: True	Response: False
Probe	True		
	False		



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The QUASA method.

QUASA assesses the two aspects of SA described previously using probe statements drawn either from the true situation or from a false one. The individual's task is to decide if the statements are true or false. The assumption is that if they can easily tell the true and false probes apart then they have good SA. This form of probe has two principal advantages:

1) They are *very* fast to administer and answer.
2) They do not require the individual to 'step back' from the situation.

The subject responds true or false to probes that represent true or false information - giving four possible combinations of probe and response (shown above). From the individual's responses, using *signal detection theory* (on which the QUASA method is based), it is possible to work out the separation of the distributions (referred to as SA') and the bias. This is referred to as 'information bias' - IB''. These two measures thus represent the aspects of SA already discussed - that is:

SA'

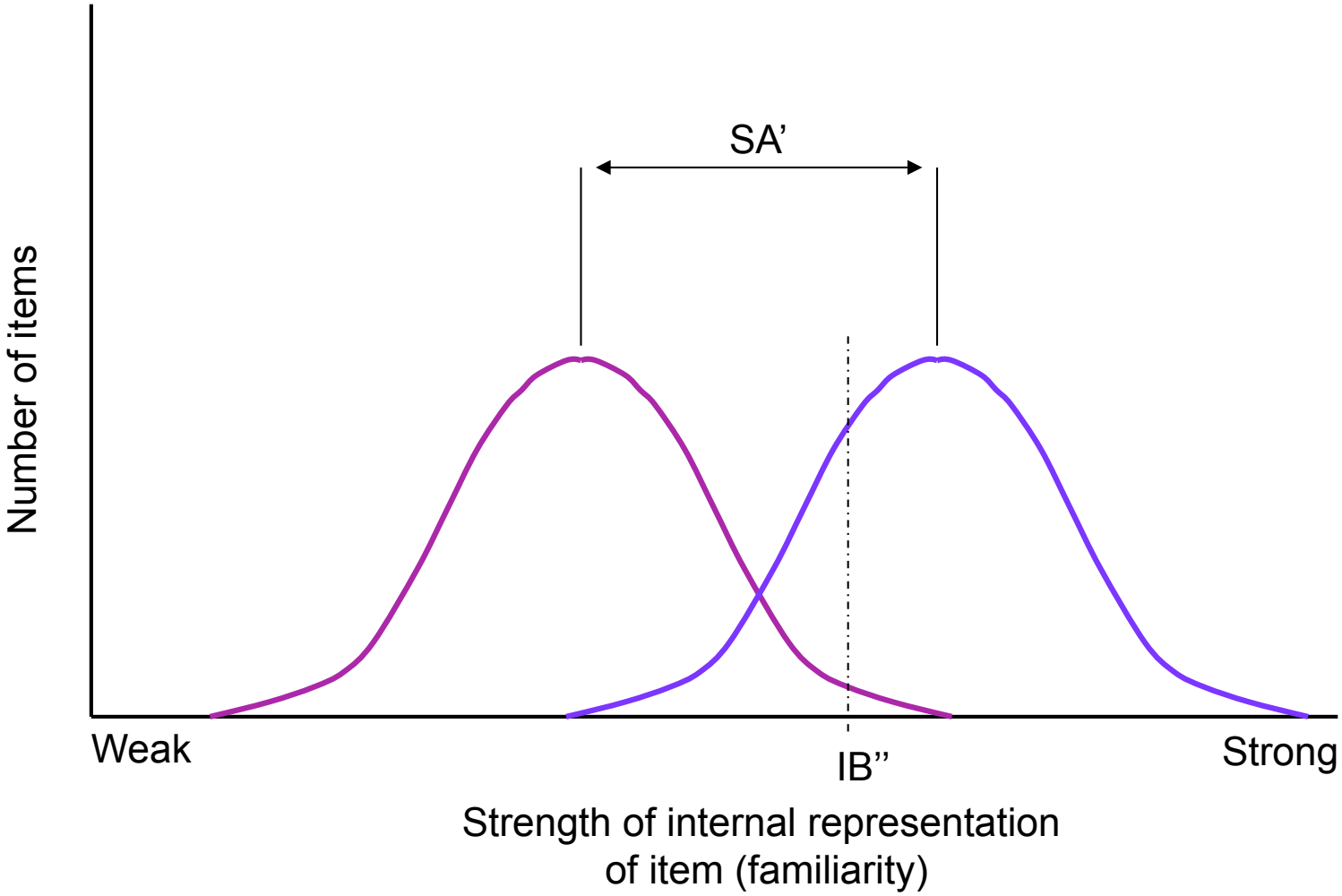
Provides a measure of how good an individual's underlying SA is - in terms of how well they can tell true from false information.

IB''

Provides a measure of how an individual uses the information at their disposal - i.e. are they accepting (and presumably basing decisions on) false information or are they rejecting true information?

BAE SYSTEMS

		Response: True	Response: False
Probe	True		
	False		



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The QUASA method (cont).

Probes are designed to address particular aspects of SA. E.g.

Perception

"There is a particular enemy unit at location **x**" T/F?

Integration

"There are enemy units in region **y**" T/F (Can only be worked out - not visible).

Projection

"At time **a** blue forces will reach position **b**" T/F

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All enemy units hidden unless blue has ‘eyes on’
All communication by written message
Commander’s movement area restricted to ‘own forces’
SA probes presented as ‘sit reps’ to HQ

BAE SYSTEMS

Testing QUASA

The ATC-Sowerby terrain model facility was used. This is a 1/300 scale model of a section of West Germany 10x2.5km ground scale - just NE of Hildesheim (near Hanover). It is part of the old 1BR corps area. Navigation features (Churchs, factories, unusual buildings, etc) are all modelled as one-offs. All buildings correctly positioned (to the level of garden sheds). Contours accurately reproduced. Painted to simulate (when filmed in B/W and inverted) a thermal return representative of a late afternoon in September.

Method

A wargame was conducted. Four commanders controlled blue forces. Red forces were controlled by umpires according to certain pre-determined characteristics for red commanders. All communication between commanders was by written message (therefore there was a complete comms record). All red units werehidden unless blue had ‘eyes on’ (I.e. a blue unit on the ground was judged able to ‘see’ the red unit).

SA probes were presented as ‘sit reps’ to HQ. All players appeared comfortable with the idea of an ill-informed management/HQ(!) asking for confirmation of information.

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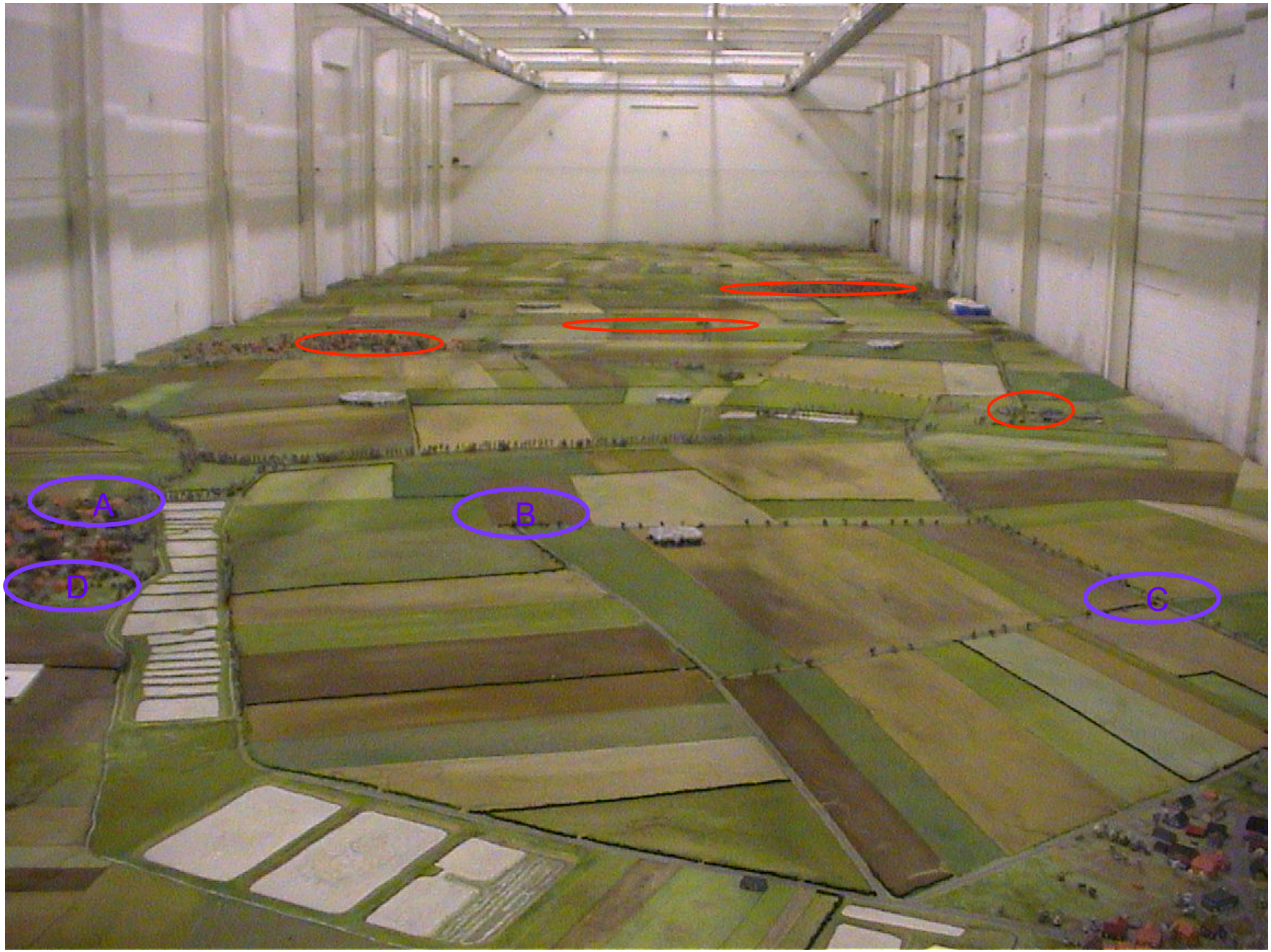

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The Scenario

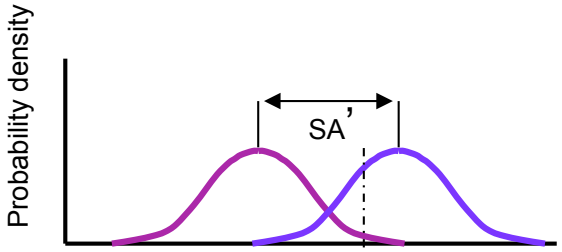
This was not intended to be a completely realistic simulation. The intention was to have a scenario with the main elements of command and control to provide a situation in which to test SA. The scenario was…...
199X. An obscure Eastern European country is collapsing, rent by internal strife. Slobnian forces have stormed through the Drogo Pass into the neighbouring state of Drossnia, looting and burning as they go. The Drossnians, rallying deep within their own territory, have repulsed the invader. Now the Slobnians are withdrawing towards their own border, plundering and destroying the towns in their path. Columns of displaced civilians are appearing on the roads; the Drossnians forces, tired after their many battles, must ensure they have homes to return to. Ugly rumours - of civilian round-ups and internment camps around the Drogo Pass - are beginning to circulate in the wake of the Slobnian withdrawal.

Blue forces

4 groups Alpha, Bravo, Charlie armour-heavy. Delta; infantry-heavy reserve.

Red forces

4 groups with, for the purposes of refereeing, distinctive ‘commander personalities’ defining how likely they are to attack/withdraw, etc.



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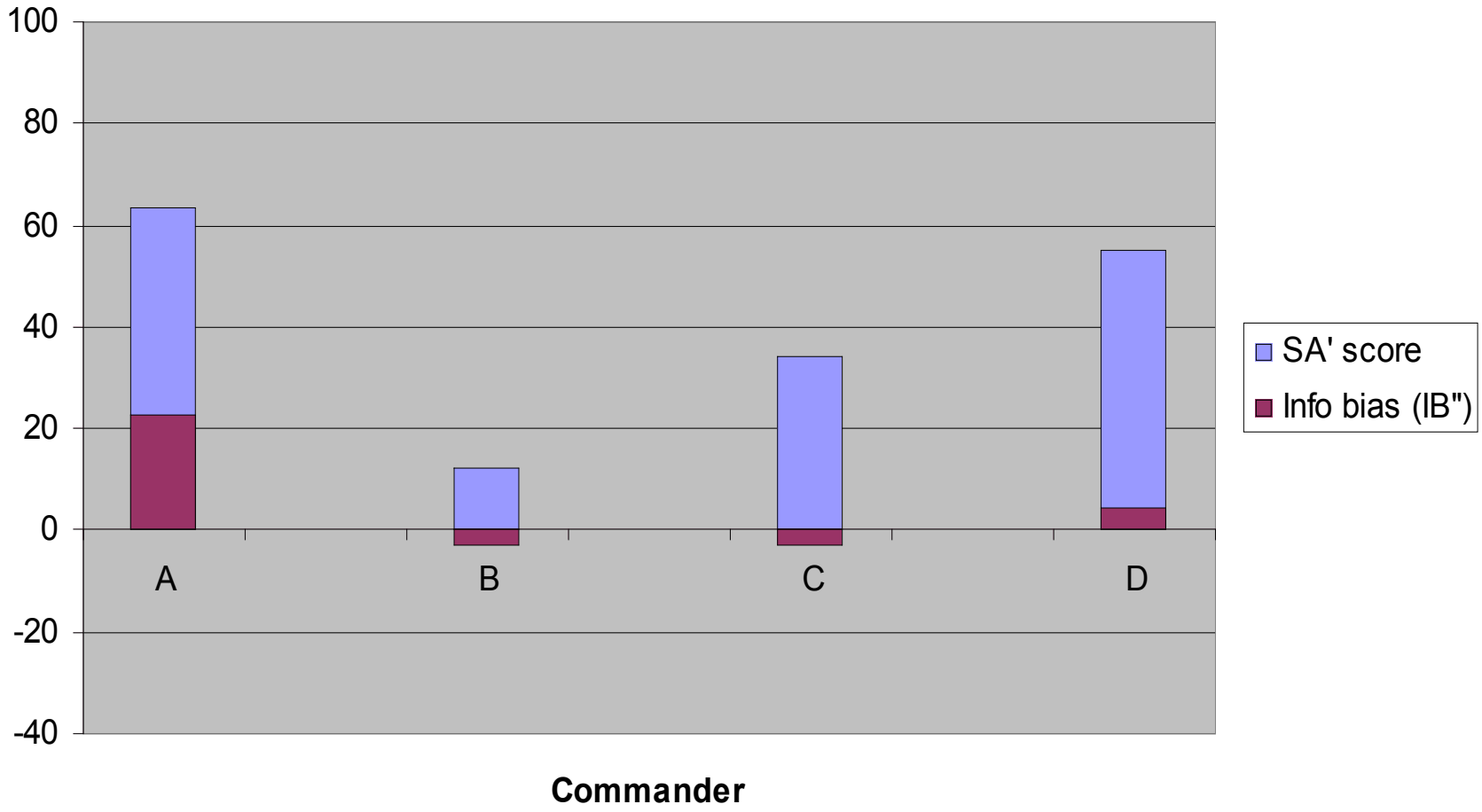
SA trial 1



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Results

As described previously, QUASA provides two scores:
SA' (SA prime). This is a measure of how easily the individual can tell true from false information - and thus represents true situational awareness.
IB" (IB double prime). This represents 'information bias'. I.e. how likely the individual is to say that false information is true or, conversely, that true information is false.
SA' score is indicated by the lighter colour bar on the graph. SA' can vary from 0 (Can't tell the two distribution apart = zero SA) to 100 (two distributions completely separate = perfect SA). Probes used need to be taken into account though (SA may *look* perfect - but if you haven't used the right probes…..).
The darker bar is information bias (IB"). Can go from -100 (Individual accepts all information as true and is therefore basing decisions on much false information) to +100 (Individual rejects all information - including true info). Loosely speaking, a large positive IB" score suggests an individual has low confidence in the information - a large negative IB" score that they have high confidence.
The method of plotting illustrates that if IB" goes positive it is 'eating into' an individuals SA - so losing real information. If IB" goes negative the individual is adding extra 'false' information to the perceived situation.
It *is* possible for SA' to go negative (up to -100). This will be considered later.

B → C “Over ford. All clear”

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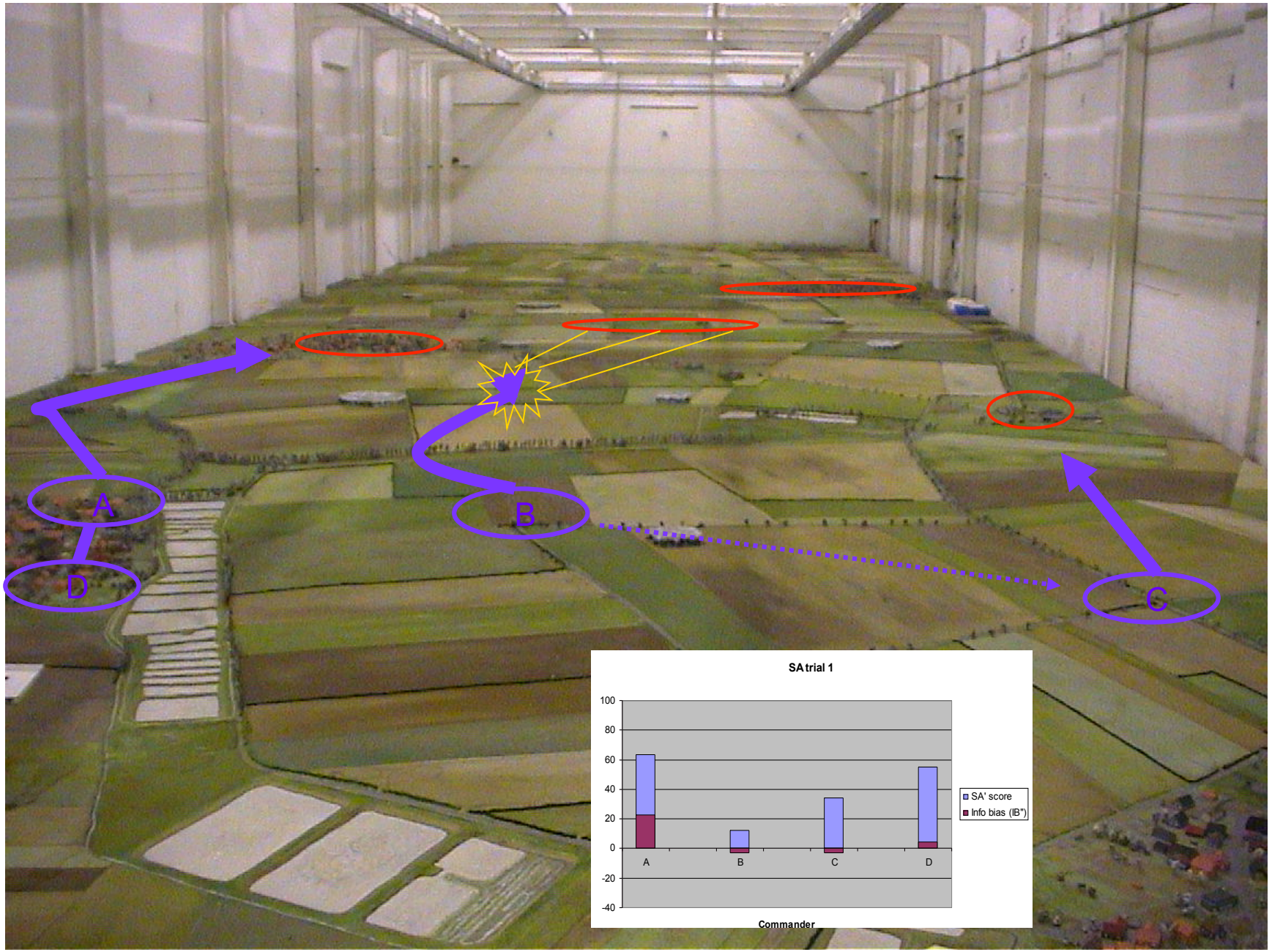

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Results compared to performance.

Bearing in mind that performance and SA *might* not be related - but almost certainly are!

This is the first of three runs of the same scenario (different players).

Charlie. Had moderate/low SA but made reasonable progress (had the advantage of material superiority).

Alpha/Delta worked in tandem. Both had good SA and were extremely effective.

Bravo. QUASA indicates a *very* low level of SA. Bravo sent a cheerful message (to Charlie), “Over ford. All clear”

Almost immediately afterwards……..

B → C “Where are you?”

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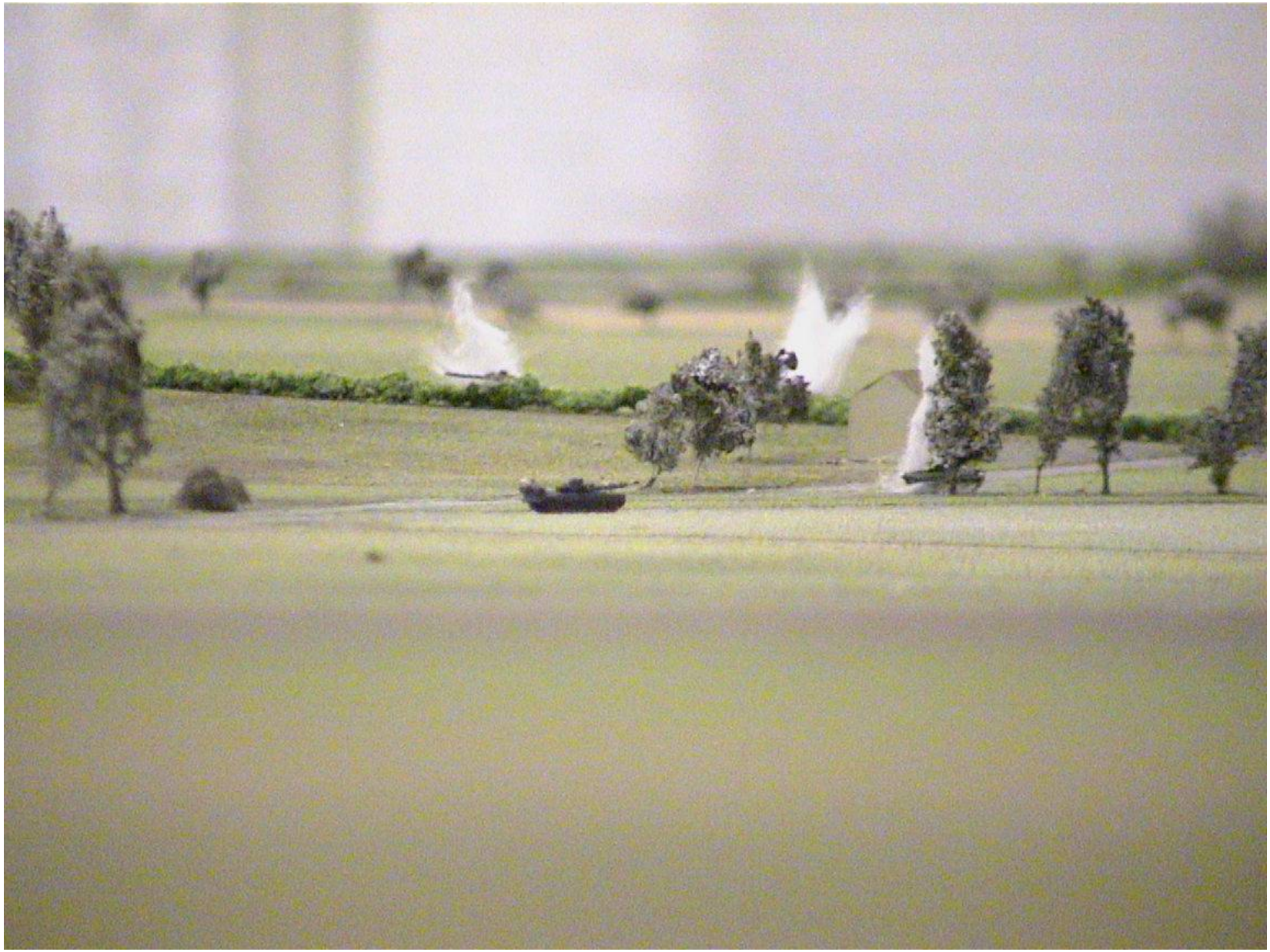

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Bravo in trouble

Bravo took heavy losses - exacerbated by apparently poor SA. Bravo made several bad errors - including taking cover on the *wrong* side of a hedge.

Also, despairing message to Charlie - “Where are you?”

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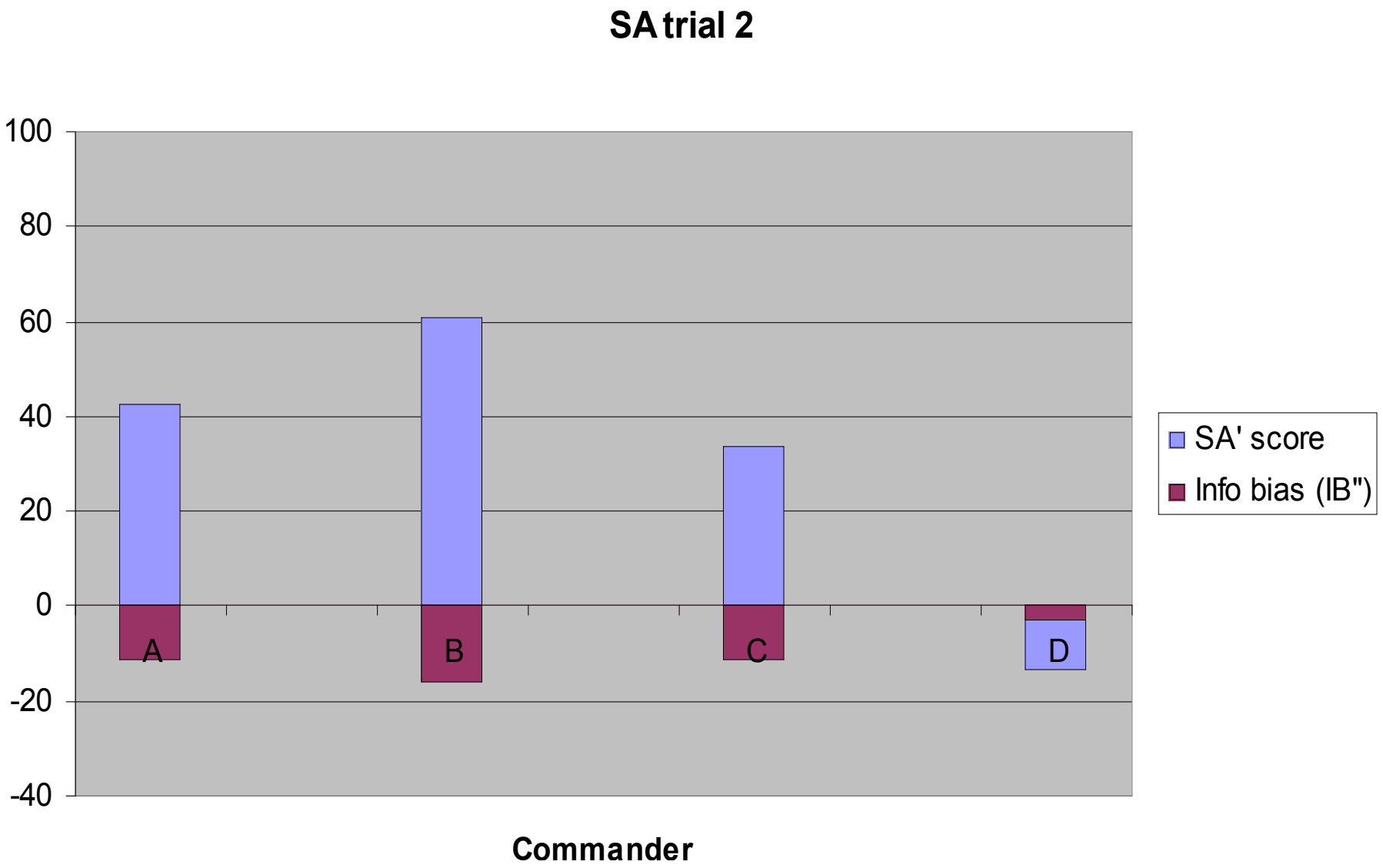
SA trial 2
100
80
60
40
20
0
-20
-40
A
B
C
D
SA' score
Info bias (IB")
Commander

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Second scenario.

Interesting, in that in this case Bravo has good SA. The commander of Bravo this time reacted differently to Bravo in the previous run. He still took a pounding (it's almost inevitable given the scenario) but Bravo's reaction this time was more appropriate to the situation.

Delta had *very* poor SA - and, in fact, never really took part in the engagement at all.

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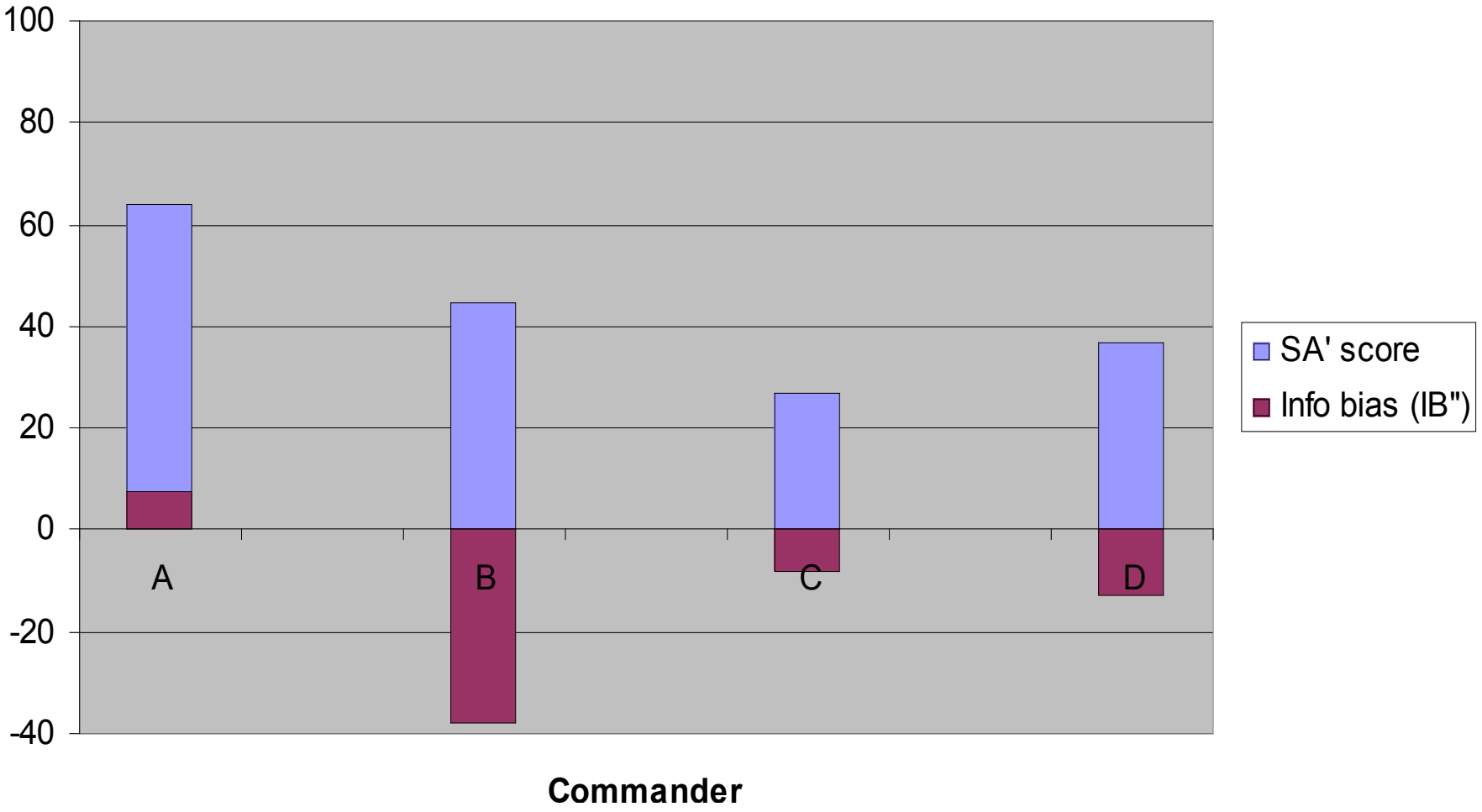
SA trial 3



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Third run

This run will be considered in a little more detail. Bravo in this case has reasonable SA - but very high *negative* IB''. This negative IB'' (taken in tandem with the nature of the probes) suggests that Bravo saw enemy forces everywhere. This demonstrates a slight feeling of paranoia - with the perception that everybody was out to get him/her. As it turned out this was not entirely unfounded.
Looking at Alpha and Delta. Alpha had a very good SA' score (the highest score in any of the trials) and little bias. Delta had fairly low SA' - but it doesn't look too bad until you start to look at things more closely……...

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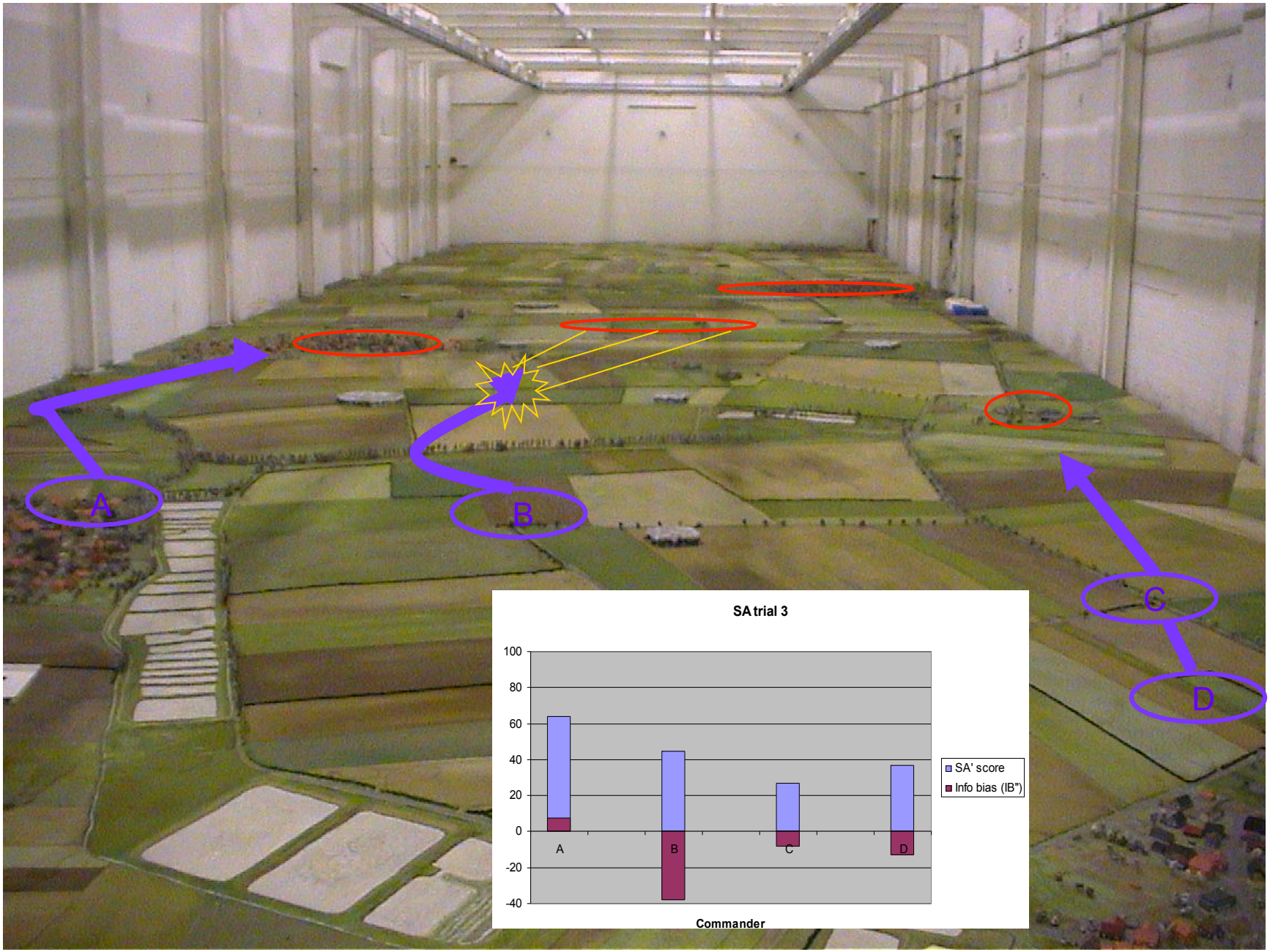
A
B
C
D
SA trial 3
100
80
60
40
20
0
-20
-40
A
B
C
D
SA' score
Info bias (IB")
Commander

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What happened?

Alpha did a *very* good job of suppressing and capturing the town shown.

Bravo (as usual) advanced and was *severely* mauled.

Charlie and Delta advanced on the right flank with Delta then cutting across towards the centre.

Considering just the SA scores for Alpha and Delta…….

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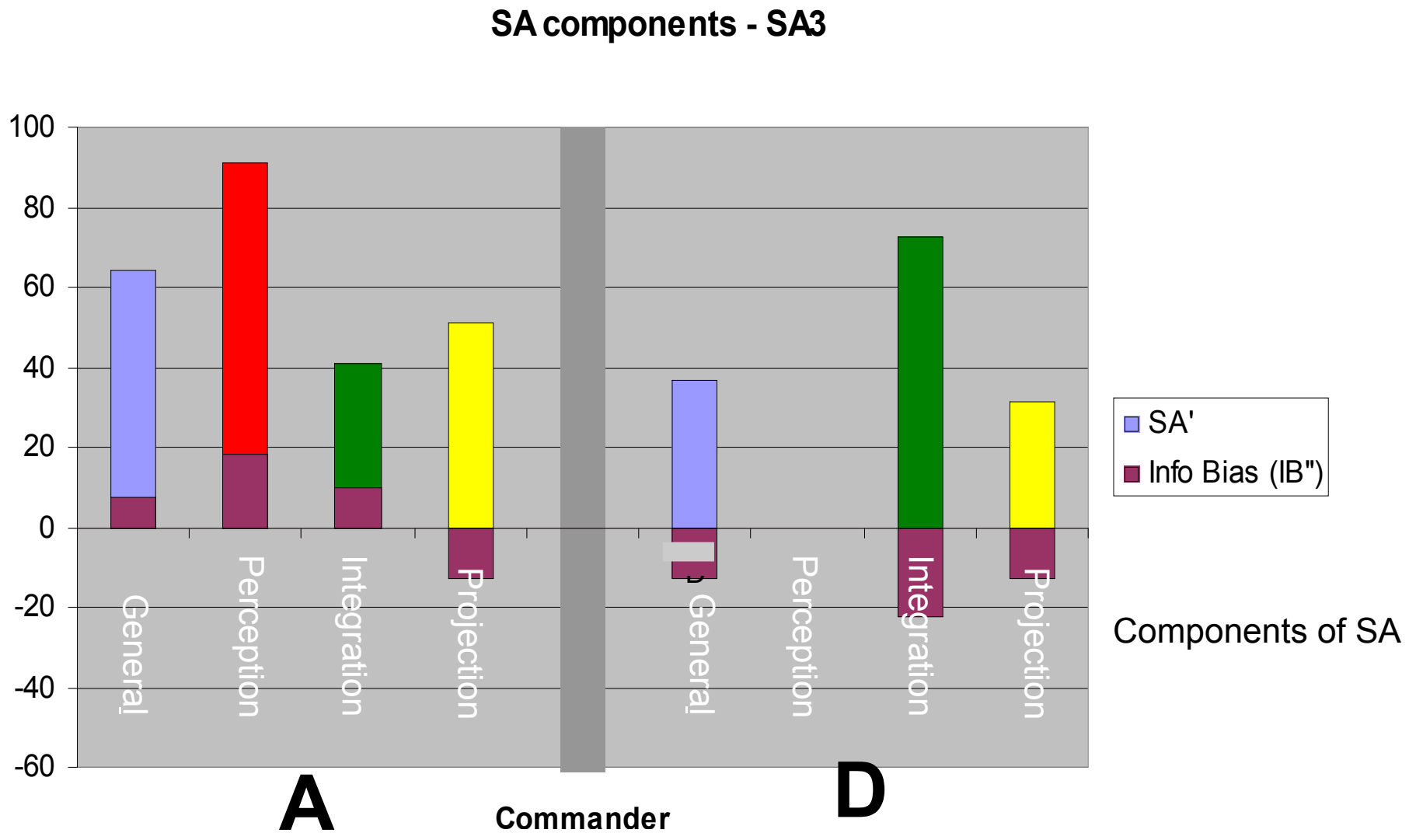
SA components - SA3
100
80
60
40
20
0
-20
-40
-60
General
Perception
Integration
Projection
General
Perception
Integration
Projection
A
Commander
D
SA'
Info Bias (IB")
Components of SA

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Components of SA

So far, we have only considered ‘general’ SA - with all components combined. The probes were designed to test all components - and the results for the individual components are shown here.

Perception
Alpha has an exceptional perception SA’ score - almost perfect.
Delta has **zero**
Integration
Alpha was average
Delta was high
Projection
Alpha was average
Delta was low

Alpha and Delta appear to be working at *different* levels of SA. I.e. Alpha appears to be working at a perceptual level - while Delta appears to be working at the level of integration - with little (or no!) overt awareness of the perceptual aspects of the situation.

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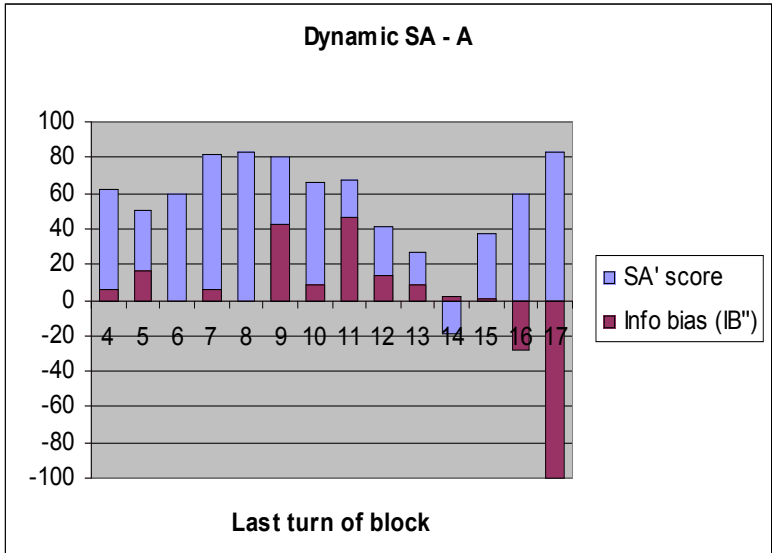
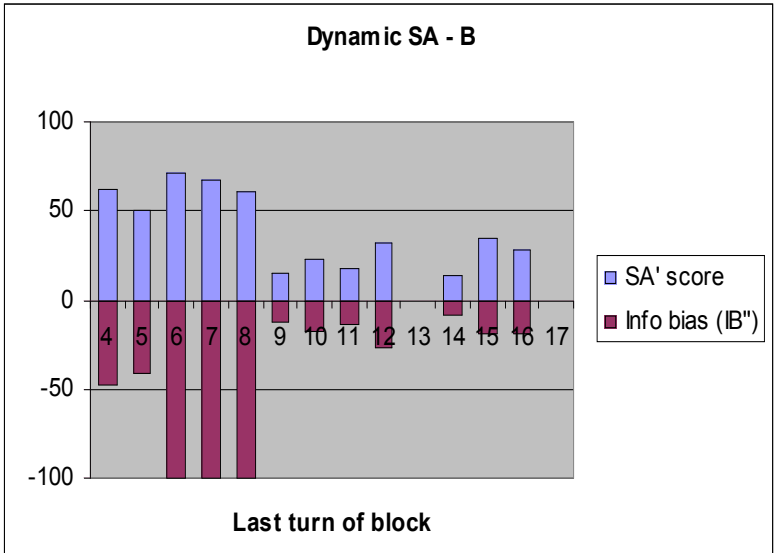
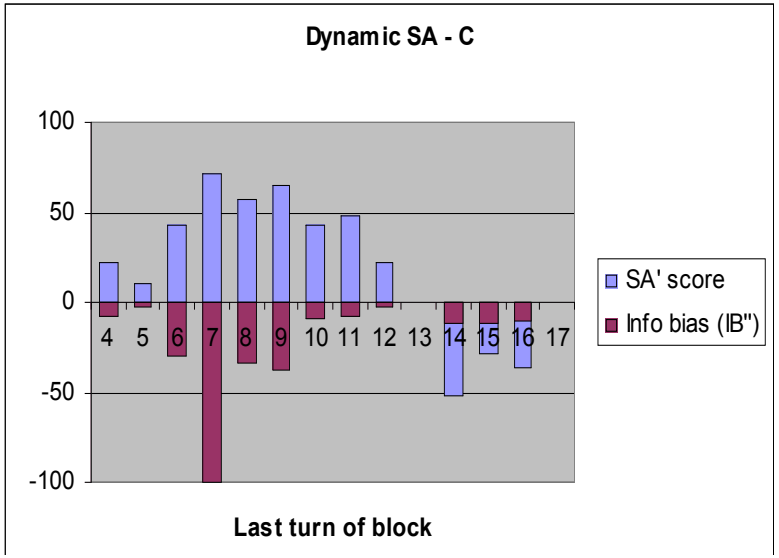
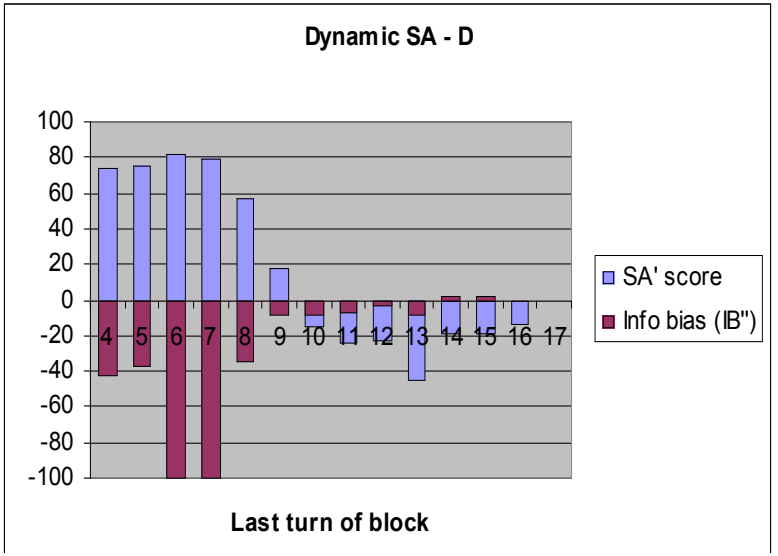




CAUTION





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Dynamic SA

This is calculated by running a five-turn 'window' over the data. So, e.g. the data for the block with last turn 7 is calculated using the probes presented in turns 3,4,5,6 and 7.

Caution
Dividing the data up in this way reduces the number of data points - and in this case is approaching the limit for this technique. Given that proviso, however, the technique appears to produce useful data.

Two points evident:
1) All players showed a loss of SA at some point. This was usually around the point when blue came under fire from attack helicopters that they couldn't (initially) see.

2) The information bias (IB'') shows a sudden increase (either positive or negative) which is coincident with (or possibly prior to) the loss of SA. This shift thus potentially provides a '***marker***' for SA loss. Ways of measuring this shift are under investigation.

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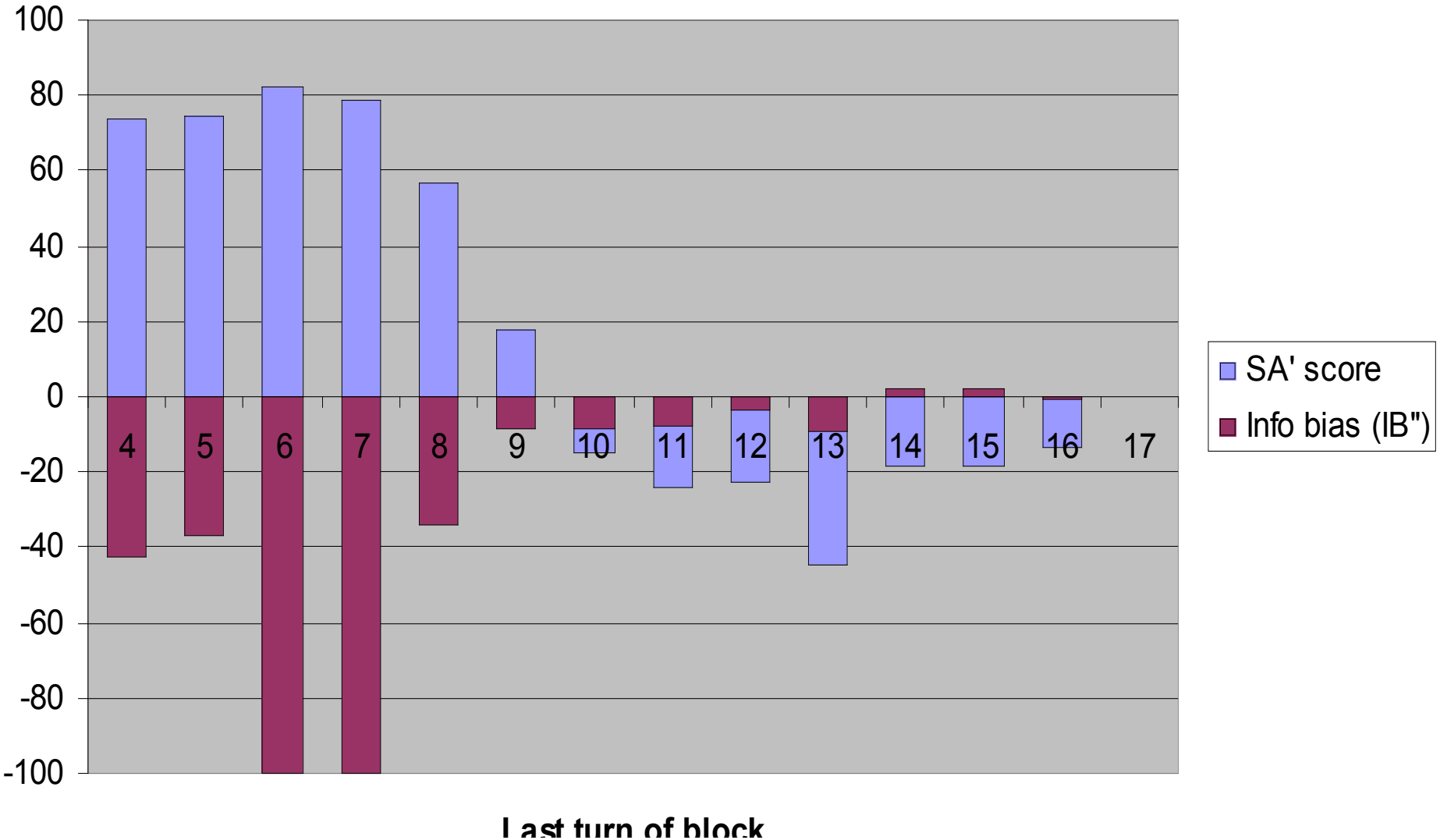
Dynamic SA - D



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Dynamic SA - Delta

Delta shows an interesting pattern of changes in SA' and IB'' here. Initially Delta has quite good SA - although the bias is a little high (suggesting that D is accepting false information as part of the situation). Suddenly the bias increases - coincident with a gradual loss of SA. Interestingly, SA' now goes negative. This suggests one of two things:

1) The delta commander does not understand how to answer the probes (unlikely).
2) Delta commander has an awareness of the *wrong* situation. SA is not just low - it is incorrect!

So, bringing in the previous results. There are two problems with Delta's SA:

1) The commander has little (or no) perceptual awareness of where enemy (and friendly forces are - only an idea of the general area where they might be.
2) At some point, what SA Delta does have is *wrong*.

What might be the consequences of this…….

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Blue-on-blue.

C and D came under fire from a sniper in the windmill (in the centre of the battlefield).
C opened fire on the windmill - killing the sniper (and, unfortunately, a number of 'friendly' civilians imprisoned there).
D advanced towards the windmill.
Meanwhile, almost the sole remaining remnant of Bravo (whose commander had the feeling that everyone was out to get him!) had arrived at the windmill (bottom left).
D came *very* close to opening fire on the unfortunate Bravo. This is despite the fact that there are several perceptual clues to indicate that the unit is part of blue. These are:
1) It's going the same way as blue (not necessarily conclusive)
2) Red units are painted green. Blue units are painted grey.
It seems unlikely that D would overlook these cues - until you consider the SA level (as revealed by QUASA) that D is working at. D had an awareness that red units were in the vicinity of the windmill - but not precisely what type or exactly where. This fits well with the measures of the components of SA presented earlier. Also, D does appear to be aware of the wrong situation (illustrated by a negative SA' score) - although red forces *were* at the windmill - by the time D arrives they have been replaced by 'friendly' forces - which D fails to realise These aspects of SA were detected by QUASA.

QUASA

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Implementation

- Not a ‘bolt-on’ tool - it must integrated
- Need to decide what questions are to be addressed
- The user *defines* the situation to be assessed
- Need to conduct a situational analysis

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Implementation

There are a number of aspects of the QUASA tool that need to be born in mind when implementing it. These are:

It is not a 'bolt-on' tool. It needs to be integrated within the scenario being tested. The rapid and relatively non-intrusive nature of the probe statements facilitates this.

It is necessary to decide what questions QUASA is designed to answer. Is the change of SA with time of interest? Is one SA component particularly important (e.g. with respect to assessing a new display)?

The QUASA user *defines* the situation to be assessed. The user selects the true and false probes that are to be used. Therefore the range and nature of the probes selected defines the situation - and it is the subject's awareness of *this* situation that is measured. This makes the QUASA method very versatile and powerful - but the data must be interpreted with care.

To generate the probes, the QUASA user must have an understanding of the situation to be assessed. Arguably, it is impossible to have any objective measure of SA without this understanding. Therefore, prior to the application of QUASA a **situational analysis** should be conducted - ideally in collaboration with relevant subject matter experts.

QUASA

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Measures…..

- Individual SA
- Components of SA
- Information bias
- Dynamic SA
- Team and shared SA

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What QUASA measures

If implemented as suggested previously, QUASA can provide a good objective measure of individual SA that appears to discriminate well between individuals and to be related to observed performance.

Individual SA can also be broken down into different components of SA (e.g. perception, integration, projection - although other divisions might be possible depending upon the probes used - e.g. relevant/not relevant to individual).

QUASA also provides a measure of information bias - this is an indication of how individuals make use of information at their disposal. This appears to be a highly reactive measure that may actually be easier to measure dynamically than SA.

Dynamic SA (and IB) can be measured. The resolution obtainable is limited only by the number of probes presented.

QUASA can be used to measure team and shared SA - but time and space prevents a discussion of that here.

Most importantly……..

QUASA

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Provides…..

Quantitative data that can be used to assess how well an individual acquires, and uses, information about a situation.

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What QUASA provides

The SA' measure that QUASA provides give an indication of how well information is being presented to, and assimilated by, the individual. If QUASA reveals a problem with this aspect then this suggests that the method of gathering and presenting information is the area that requires attention. I.e. effort should be directed towards ensuring that the individual gets the right information at the right time and in a form that can be easily assimilated. Thus, any changes might be directed towards improving information displays or communications.

The IB'' measure gives an indication of how the individual is using the information. If there is a problem in this area then the action taken would need to be different. For instance, it might be necessary to examine the individuals training - or experience. For example, an individual might be using a display that provides unreliable data (which the user is aware of - and therefore has little confidence in the display). This would show as poor SA' *and* IB'' scores. Action, in the first instance would need to be directed towards improving the display. Once this had happened it might be the case that SA' would improve - but IB'' might still be poor - as the user may still have little confidence in the display due to past experience. In this case, training (for instance) may be required to restore confidence in the display - and the effectiveness of this training could be assessed by QUASA..

But above all…...

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QUASA seems to work.

The data presented here are only a fraction of those obtained in the three trials so far. QUASA, however, appears to provide quantitative data that can be linked to observed performance/behaviour (providing criterion validity) and, importantly, can explain and predict certain types of behaviour - such as that discussed here leading to a near blue-on-blue.

Development and validation of the QUASA tool is ongoing……..

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The End

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