Multisensorisk information: Från stridspilot till schizofren

Lars Eriksson

Multisensorisk information: Från stridspilot till schizofren

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Aviation, Space, and Environmental Medicine 2007

RESEARCH ARTICLE

Tactile Cueing Effects on Performance in Simulated Aerial Combat with High Acceleration

Jan B. F. van Erp, Lars Eriksson, Britta Levin, Otto Carlander, J. A. Veltman, and Wouter K. Vos

Stridsfordon 90

Human Factors 2012

Enhanced Perception and Performance by Multimodal Threat Cueing in Simulated Combat Vehicle

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Age, cognitive load, and multimodal effects on driver response to directional warning

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ARTICLE INFO

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ABSTRACT

Inattention can be considered a primary cause of vehicular accidents or crashes, and in-car warning signals are applied to alert the driver to take action even in automated vehicles. Because of age related decline of the older driver's abilities, in-car warning signals may need adjustment to the older driver. We therefore investigated the effects of uni-, bi- and trimodal directional warnings (i.e., light, sound, vibration) on young and older drivers' responses in a driving simulator. A young group of 15 drivers (20–25 years of age) and an older group of 16 drivers (65–79 years of age) participated. In the simulations, warning signal was presented at the left, the center, or the right in front of the participant. With a warning at the left, the center, and the right the correct response was to steer to the right, brake, and steer to the left, respectively. The main results showed the older drivers' responses were slower for each type of warning compared with the young drivers' responses. Overall, the responses were slower with an added cognitively loading task. The only multimodal type of warning inducing overall faster response than its constituent warning types was the vibration-sound, and only for the older drivers. Additionally, with the groups' responses collapsed, such a true multimodal effect on response time also showed for the center vibration-sound warning (i.e., braking response). The only multimodal warning showing clear reduction in response errors compared with its constituent warning types was the vibration-sound for the older drivers during extra cognitive load. The main conclusion is that older drivers can benefit from bimodal warning, as compared with unimodal, in terms of faster and more accurate response. The potential superiority of trimodal warning is nevertheless argued.

1. Introduction

Safe car driving requires appropriate use of finite perceptual and cognitive resources, and inattention is considered a primary cause of vehicular accidents or crashes (e.g., Bärgman et al., 2015; Klauer et al., 2014; Victor, 2011). In-car warning signals can be applied to alert the driver of impending danger, such as with a switched-on red light in front of the driver just below the windshield on the dashboard to warn for a coming head-on collision. There also is a continued need for effective warning signals for some time regardless of whether the future driver will supervise or remain in full control of the car (De Winter et al., 2014; Lu et al., 2016). For example, the study by Petermeijer et al. (2017) underlines the need for a highly automated vehicle to provide an effective take-over request (TOR) when its operational limits are reached, which requires some warning signal that is reliably effective. The demand on perceptual and cognitive resources can though be extra challenging to the older driver because the perceptual, cognitive, and motor abilities normally decline with aging (Collins McLaughlin and Mayhorn, 2014; Dieuleveult et al., 2017; Freiherr et al., 2013; Thompson et al., 2012). Additionally, *"both the proportion and absolute number of older people in populations around the world are increasing dramatically"* (World Health Organization, 2015, p. 43), which essentially means an increase of older drivers (i.e., if they retain their license and continue driving). This in conjunction with the driver inattention problem may pose a growing safety issue, and in-car warning signals may need adjustment to the older driver's capabilities (Aksan et al., 2013; Cicchino and McCartt, 2015; Horberry et al., 2006; Laurienti et al., 2006).

Non-driving secondary tasks cause extra load that delay the driver's responses (e.g., Lee et al., 2009), and it has been estimated that over 30% of serious crashes are associated with the driver's engagement in some sort of secondary task (McEvoy et al., 2007). Staubach (2009) also reveals that distraction leads to a number of types of crashes, including those occurring at crossroads and in lane departures. The study by Young et al. (2013), for example, indicates which driver errors are more likely during distraction, and some of the reported high-criticality

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Research Paper

A systematic review of the neural correlates of multisensory integration in schizophrenia

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ARTICLE INFO

Keywords:
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ABSTRACT

Multisensory integration (MSI), in which sensory signals from different modalities are unified, is necessary for our comprehensive perception of and effective adaptation to the objects and events around us. However, individuals with schizophrenia suffer from impairments in MSI, which could explain typical symptoms like hallucination and reality distortion. Because the neural correlates of aberrant MSI in schizophrenia help us understand the physiognomy of this psychiatric disorder, we performed a systematic review of the current research on this subject. The literature search concerned investigated MSI in diagnosed schizophrenia patients compared to healthy controls using brain imaging. Seventeen of 317 identified studies were finally included. To assess risk of bias, the Newcastle-Ottawa quality assessment was used, and the review was written according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA). The results indicated that multisensory processes in schizophrenia are associated with aberrant, mainly reduced, neural activity in several brain regions, as measured by event-related potentials, oscillations, activity and connectivity. The conclusion is that a fronto-temporal region, comprising the frontal inferior gyrus, middle temporal gyrus and superior temporal gyrus/sulcus, along with the fusiform gyrus and dorsal visual stream in the occipital-parietal lobe are possible key regions of deficient MSI in schizophrenia.

1. Introduction

We constantly encounter an abundance of sensory information that has to be successfully organized for us to be able to make sense of it. The converging processes of sensory modalities (e.g., auditory, visual, tactile modalities) required to generate a meaningful and coherent perception underlie the concept of multisensory integration (MSI; Talsma et al., 2010). For example, during a conversation with a friend in a busy restaurant, you will perceptually process your friend's voice (i.e., auditory stimuli) and articulations (i.e., visual stimuli) concurrently and rapidly to integrate them. This integration will increase your speech perception because MSI enhances perceptual acuity and improves detection, discrimination and response speed (Wallace et al., 2020). MSI does not only help us avoid cognitive overload and create meaning in the constant sensory information flood (Jensen et al., 2019), but also plays a crucial role for our daily functioning and well-being through guiding our responses to the complex outer world (Tseng et al., 2015).

Different types of research paradigms have been used to study the effects of MSI on behavior. Some focus on multisensory illusions that show how information from different sensory modalities can fuse together into one percept. One example is the *McGurk effect* in which a video of a person saying one phoneme (e.g., 'ga') is dubbed with a recording of another phoneme (e.g., 'ba') and resulting in the perceived illusion of a mixed phoneme (e.g., 'da') (McGurk & MacDonald, 1976). Other studies focus on the performance enhancement multisensory stimuli enable. One example is the redundant signals effect (RSE), which shows that responses are faster and more precise with stimuli presented in multiple sensory modalities compared to a single modality (Hershenson, 1962; Kinchla, 1974). Groundbreaking electrophysiology studies of neurons in the superior colliculus discovered important principles for MSI (Meredith and Stein, 1983, 1986; Stein and Stanford, 2008). According to the principle of inverse effectiveness, multisensory enhancement is greater if the unisensory signals are of low intensity. In addition, multisensory facilitation is maximal when stimuli from different modalities are presented at the same time (temporal rule) at around the same place (spatial rule), and decreases with increased inter-stimulus onset (Stone et al., 2014).

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Tactile cueing effects on performance in simulated aerial combat with high acceleration

Van Erp, Eriksson, Levin, Carlander, Veltman & Vos

Aviation, Space, and Environmental Medicine 2007

RESEARCH ARTICLE

Tactile Cueing Effects on Performance in Simulated Aerial Combat with High Acceleration

Jan B. F. van Erp, Lars Eriksson, Britta Levin, Otto Carlander, J. A. Veltman, and Wouter K. Vos

van Erp JBF, Eriksson L, Levin B, Carlander O, Veltman JA, Vos WK. *Tactile cueing effects on performance in simulated aerial combat with high acceleration.* Aviat Space Environ Med 2007; 78:1128–34.

Introduction: Recent evidence indicates that vibrotactile displays can potentially reduce the risk of sensory and cognitive overload. Before these displays can be introduced in super agile aircraft, it must be ascertained that vibratory stimuli can be sensed and interpreted by pilots subjected to high G loads. ***Methods:*** Each of 9 pilots intercepted 32 targets in the Swedish Dynamic Flight Simulator. Targets were indicated on simulated standard Gripen visual displays. In addition, in half of the trials target direction was also displayed on a 60-element tactile torso display. Performance measures and subjective ratings were recorded. ***Results:*** Each pilot pulled G peaks above +8 G_z. With tactile cueing present, mean reaction time was reduced from 1458 ms (SE = 54) to 1245 ms (SE = 88). Mean total chase time for targets that popped up behind the pilot's aircraft was reduced from 13 s (SE = 0.45) to 12 s (SE = 0.41). Pilots rated the tactile display favorably over the visual displays at target pop-up on the easiness of detecting a threat presence and on the clarity of initial position of the threats. ***Discussion:*** This study is the first to show that tactile display information is perceivable and useful in hypergravity (up to +9 G_z). The results show that the tactile display can capture attention at threat pop-up and improve threat awareness for threats in the back, even in the presence of high-end visual displays. It is expected that the added value of tactile displays may further increase after formal training and in situations of unexpected target pop-up.

Keywords: tactile perception, tactile display, human performance, multi-sensory, cockpit displays.

IN RECENT YEARS, tactile displays have proven to be a valuable addition to the set of cockpit instruments in both rotary- and fixed-wing aircraft (4,10,11,12,17–19). Tactile displays use mechanoreceptors in the skin to transfer tactical or flight-related information without the risk of overloading the pilot's vision or hearing. The most common tactile signal used in vehicle control is a localized vibration, for example presented through elements (also called tactors) in seat cushions, safety belts, or clothing. The concept of tactile torso displays for aviation and space operations was introduced in the nineties by Rupert (11) [for a historical perspective on tactile displays, see (3)]. A major advantage of this concept is that a localized vibration on the torso can act as a proverbial tap on the shoulder. For instance, van Erp (15) showed that a localized vibration on the torso was easily coupled to spatial information like the direction to a waypoint or a threat.

In the last decade, several research efforts have focused on validating the potential of tactile displays in aviation and microgravity. For example, Craig and colleagues presented drift information to helicopter pilots to improve high hover performance and simulated shipboard landings (4). In a laboratory evaluation, van Erp and colleagues showed that low hover and low-level flight performance of helicopter pilots could be improved by adding a tactile cockpit instrument (18,19). In a field study, they also showed that a tactile display can be used to present waypoint navigation information (17). More recently, successful applications in recovery from unusual attitudes and in counteracting spatial disorientation were presented in several field studies (10,16).

One of the challenges in applying tactile displays in aviation is to determine the effect of external stressors such as whole body vibration and altered gravito-inertial environments on perception and interpretation of vibrotactile signals. These issues have only recently been investigated. Both operational and laboratory studies have shown that the usefulness of tactile displays is not negatively affected under conditions of whole body vibration (9,17). This is probably because the vibration frequency of the tactors is much higher than the frequency ranges of vehicle vibration. With vibration frequencies on the order of 150 Hz, tactors primarily activate mechanoreceptors in the skin [the Pacinian corpuscles (2)] that are not responsive to vehicle vibration frequencies, which are typically below 50 Hz (1). With respect to reduced gravity, several studies have shown that the effects on tactile perception are small, if present at all (13,14,16). However, there is no systematic knowledge available yet on the effects of hypergravity on pilot's perception and performance with a tactile display. Several factors exist that are capable of negatively affecting tactile perception under high G load. These

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Fixed Wing: Fighter Aircraft

Fighter Aircraft Environment

Tactile cueing at high G-loads?

Previous studies in human centrifuge:

Van Veen & van Erp (2001):	+6Gz
Rupert & McGrath (2005):	+6.5Gz

Tactile cues possible to perceive at fairly high G-loads

Present Study

Scenario of threat detection and threat intercept
Up to +9Gz in the Swedish Dynamic Flight Simulator (DFS)

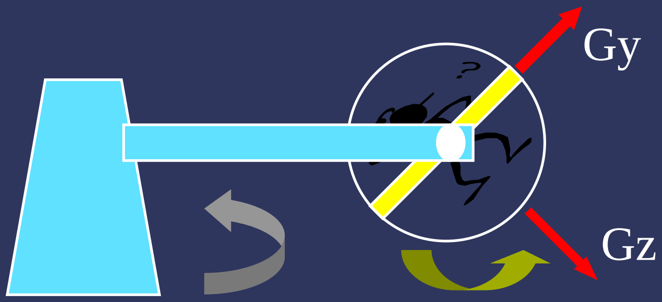
First study to test tactile cueing for fighter pilots in an operational setting allowing G-loads with rapid onset rate and up to +9Gz

Experiment

Participants

Nine fighter pilots from the Swedish Air Force
Flight experience: Mean of 1605 hrs in fighter aircraft

Swedish Dynamic Flight Simulator (DFS)



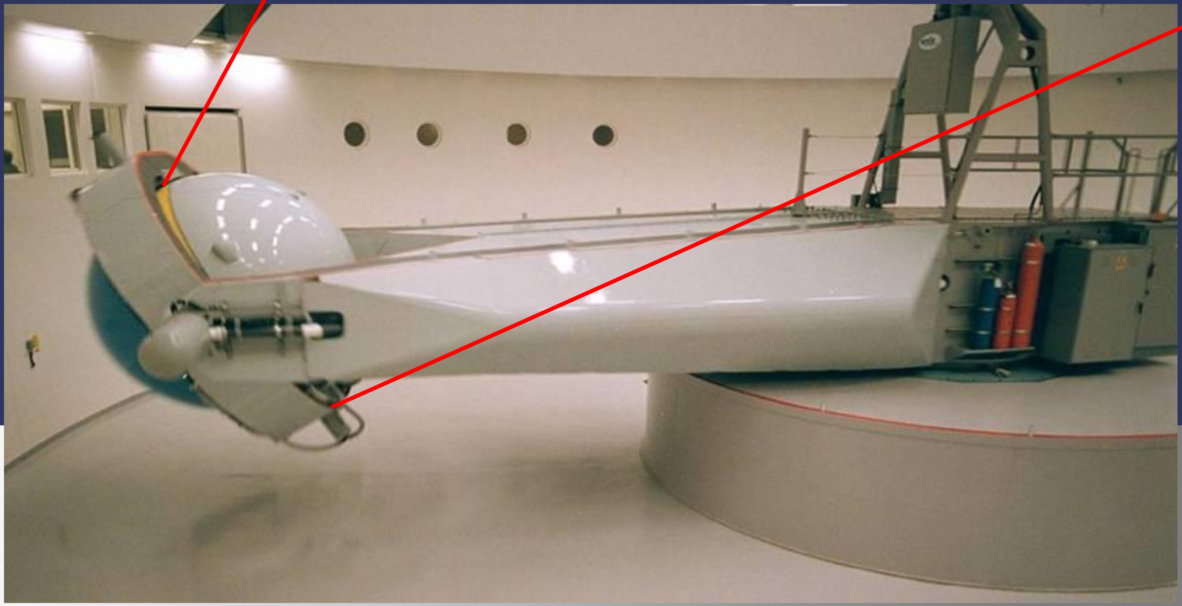
- 2-axes 3 degrees of freedom human centrifuge
- flight simulation system: aerodynamic model of Gripen fighter aircraft
- closed-loop control: pilot 'flies the DFS like an aircraft'

Gripen

Experiment

DFS

- mock-up of Gripen cockpit in gondola
- out-the-window displays: 100° × 30°
- textured open flight database
- data acquisition equipment



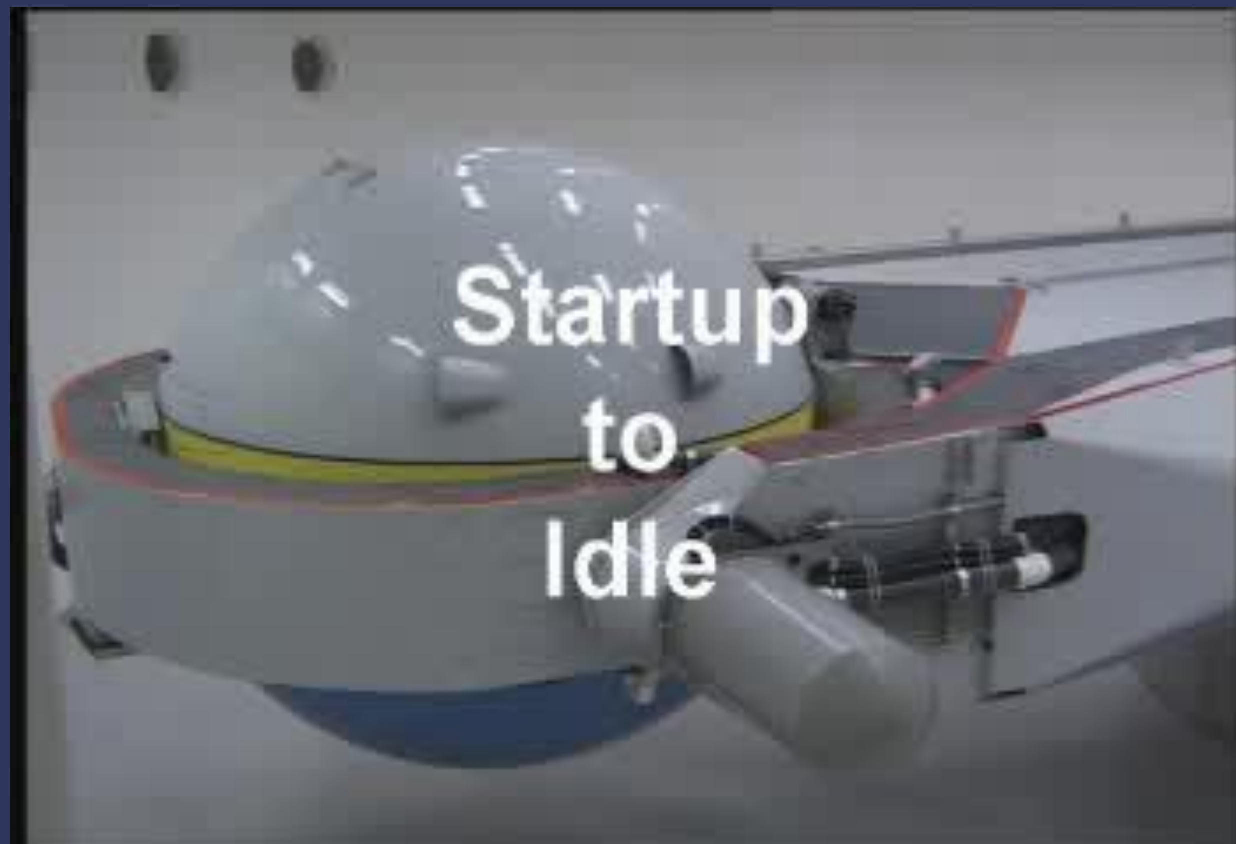
Experiment

DFS

- high onset/offset rates
- pilot in control of G-forces

Used in experiment:
- Max +Gz onset: 6G/s
- Max +Gz: 9G

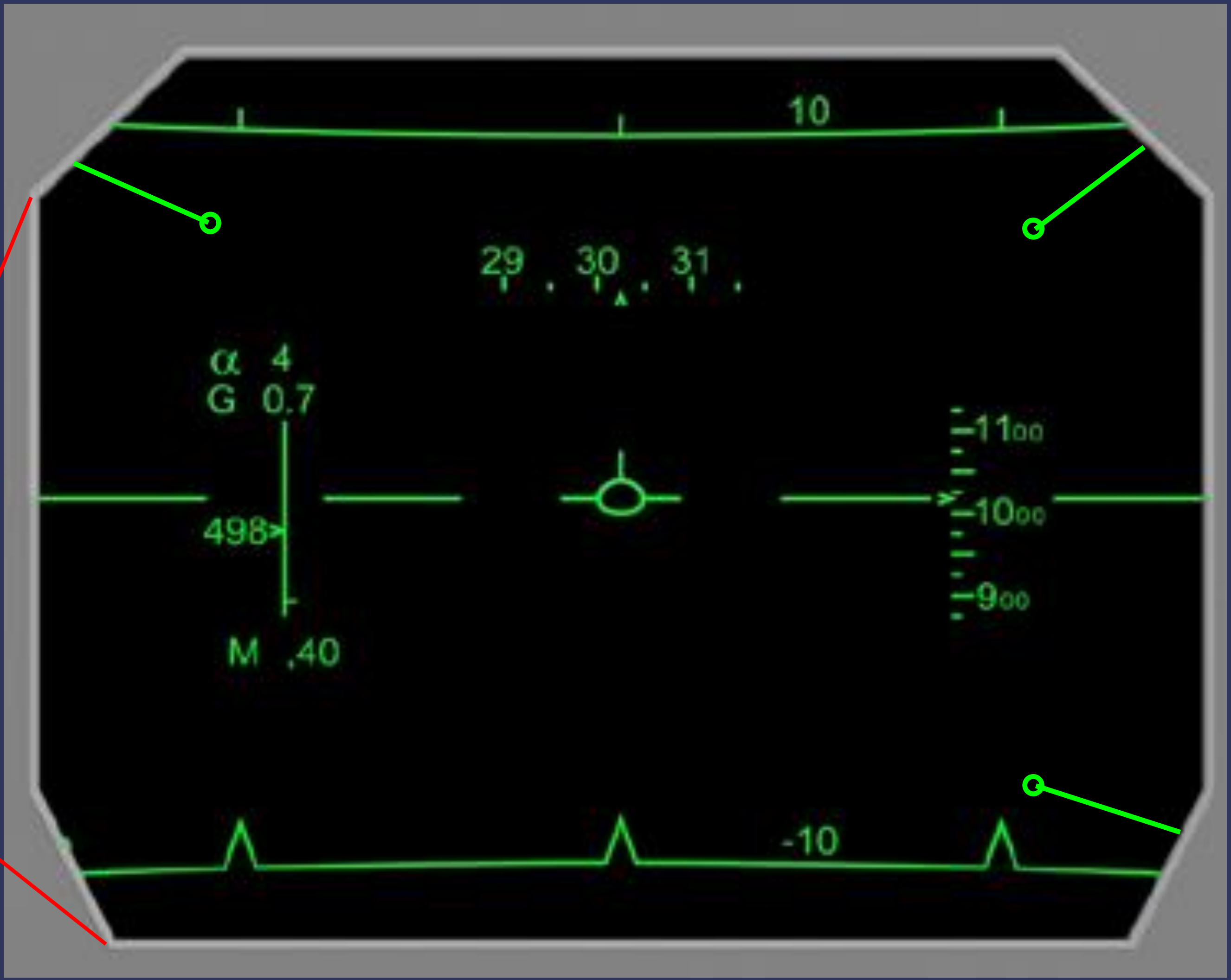
<u>Capability</u>
Max +Gz onset rate: 10G/s
Max +Gz: 15G

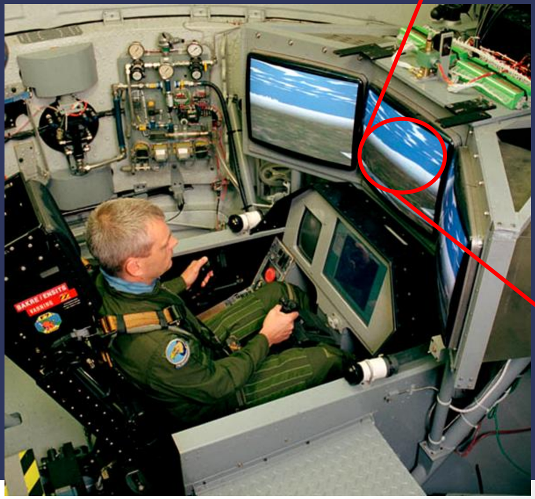


Experiment

Gripen Head-Up Display (HUD)

- visual threat cue
- 2D direction to threat





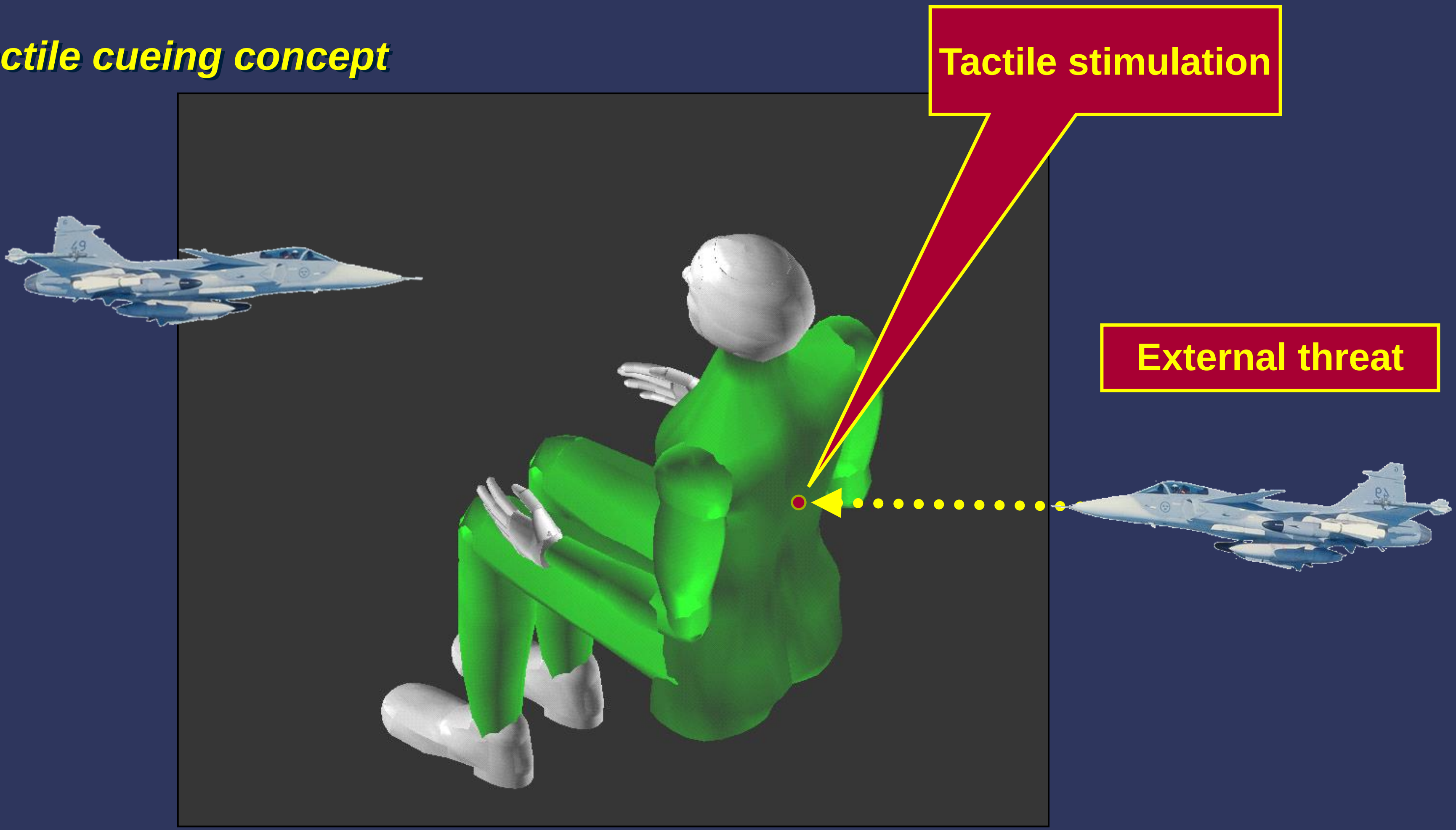
Experiment

TNO Tactile Torso Display (TTTD)

- tactile threat cue
- “3D” direction to threat

Experiment

Tactile cueing concept



Experiment

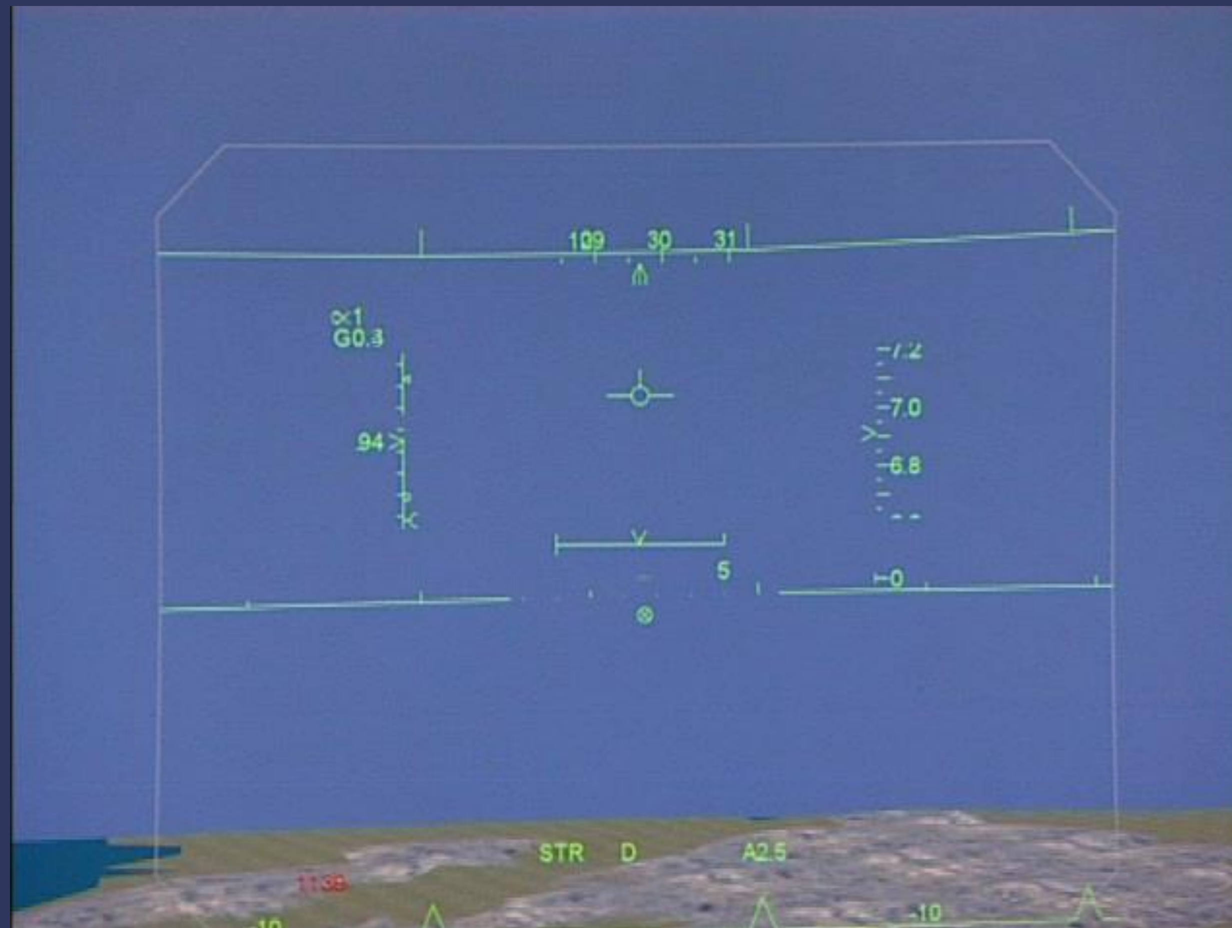
- each fighter pilot intercepting 32 threats in less than 60 min

- 16 threats cued with HUD and Head-Down Displays

- 16 threats cued with Tactile Display added

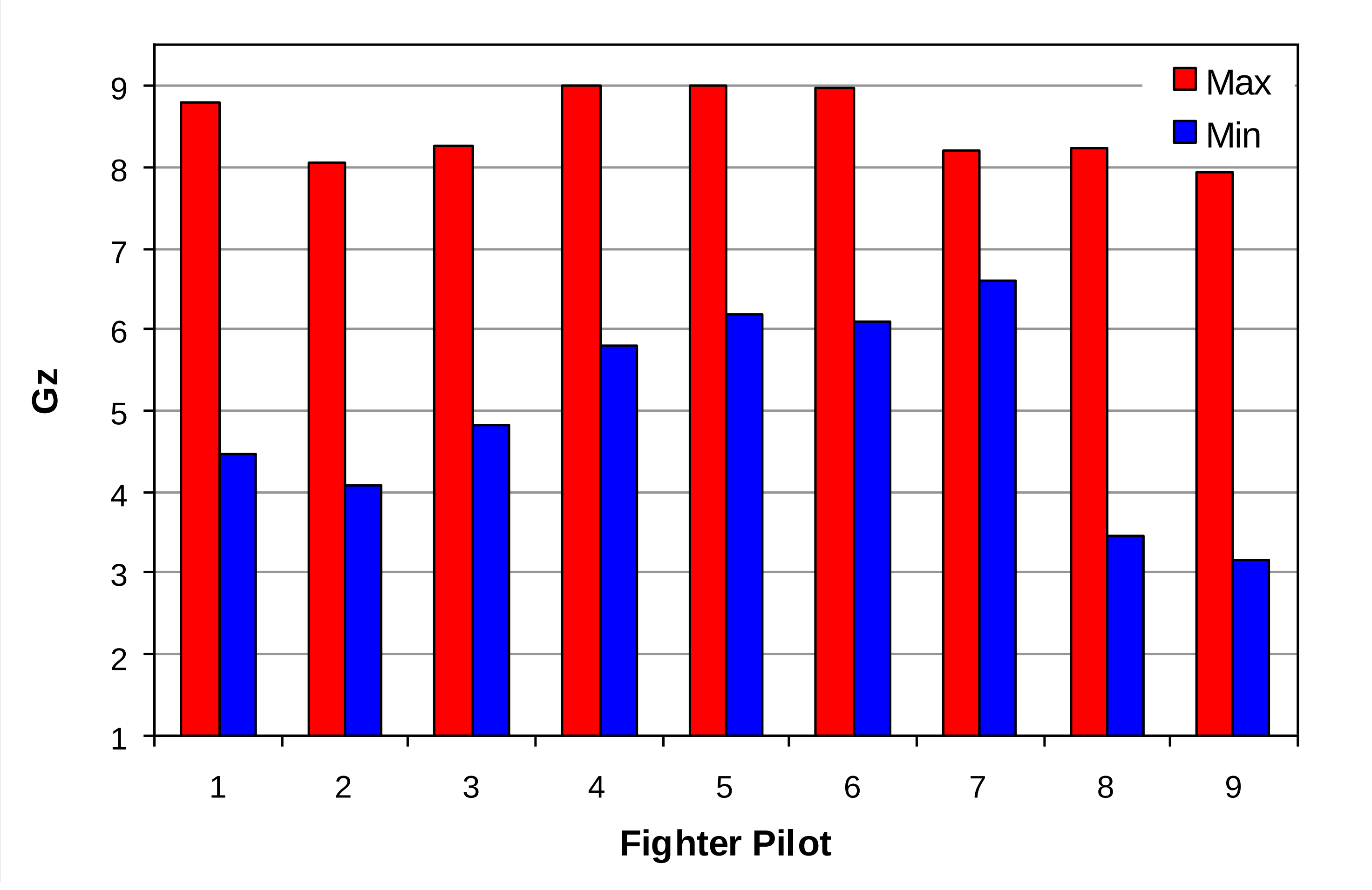
- manoeuvre as quickly as possible towards threat

- threat defeated: threat symbol in centre of HUD



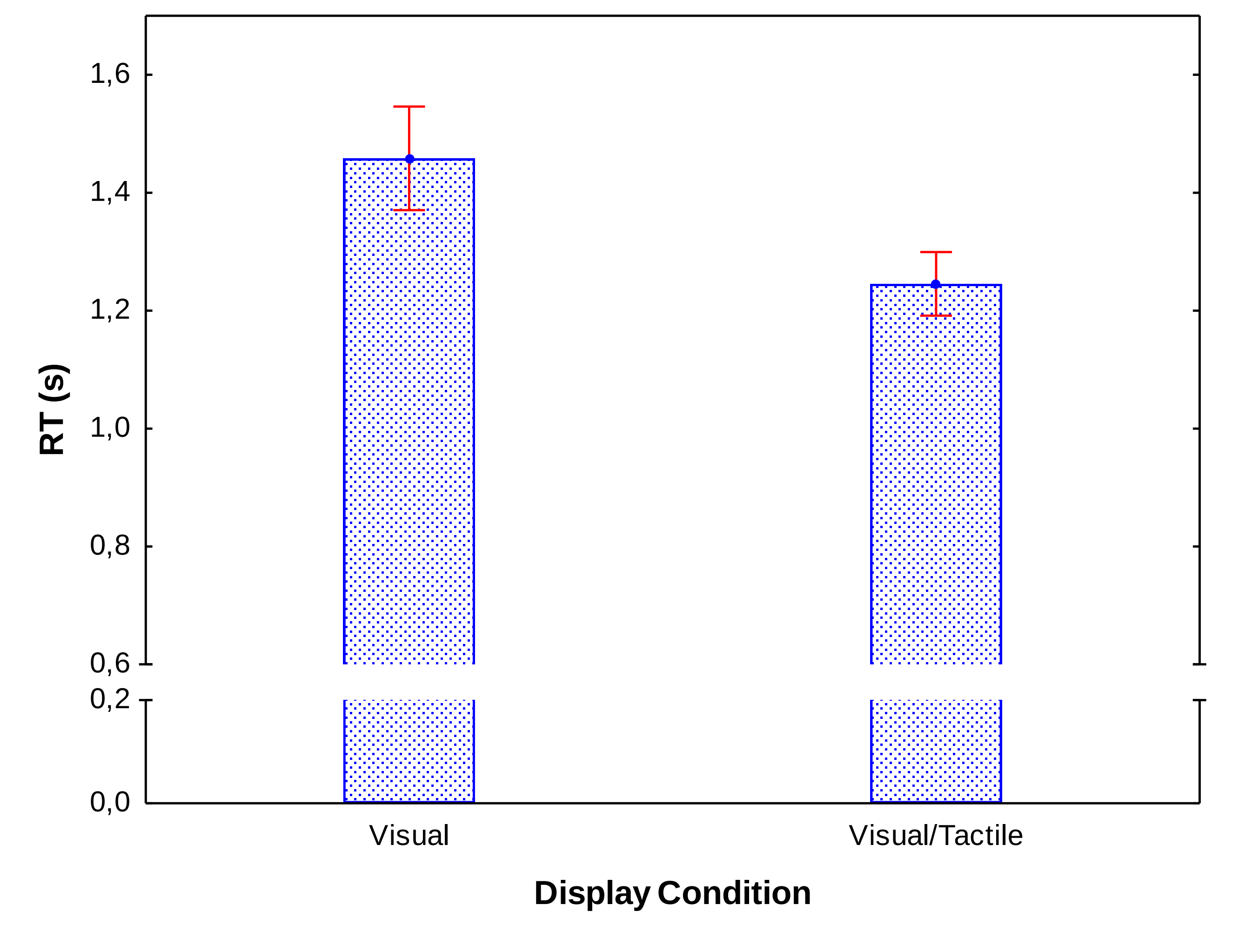
Some results

Each pilot's max and min +Gz-peaks of the 32 threat intercepts
(Means of Gz-peaks ranging from +5.9 to +8.0 Gz)



Some results

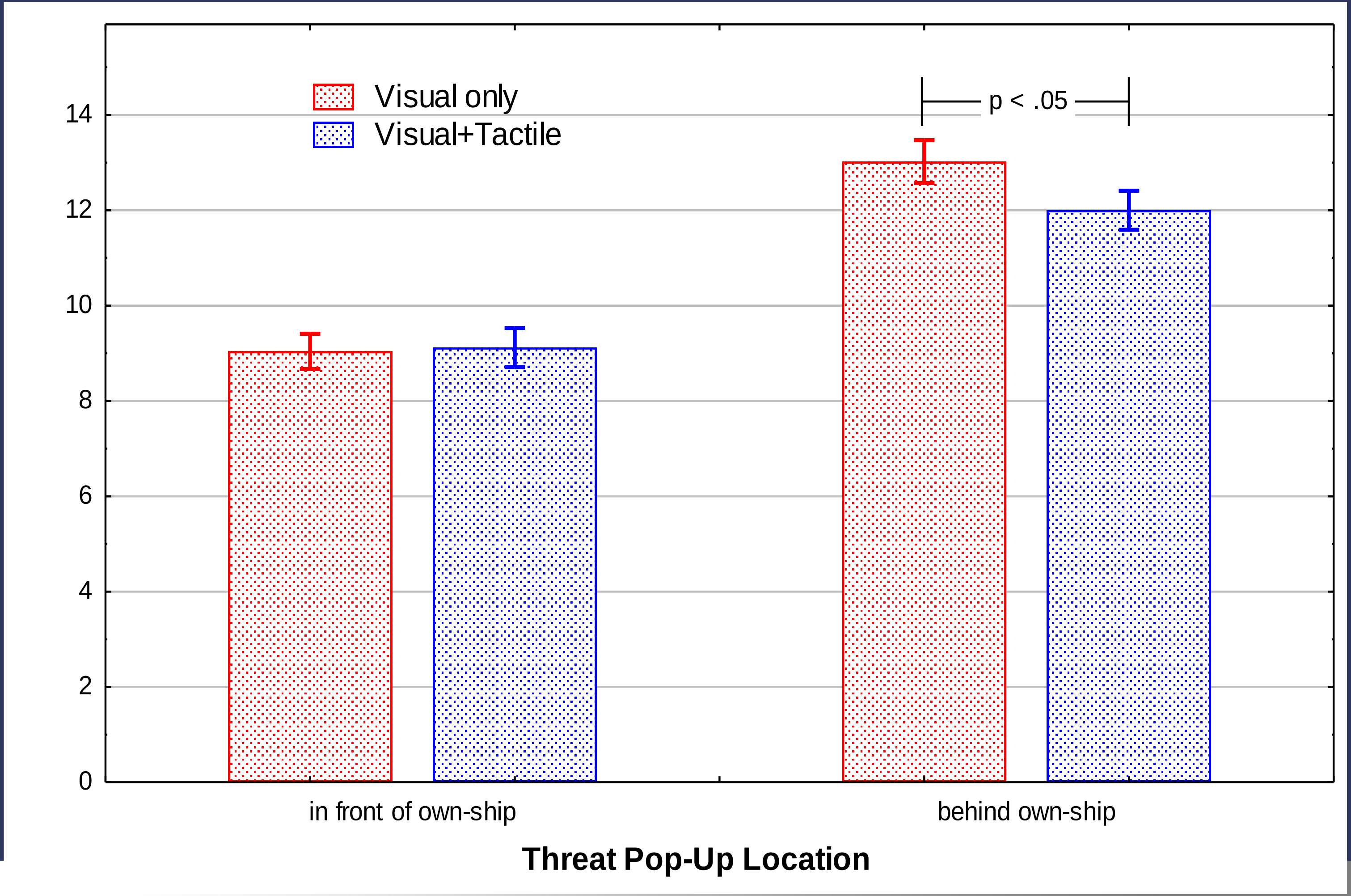
Reaction time (RT): from threat pop-up to 10° roll to threat
About 200 ms faster with tactile vest added



Some results

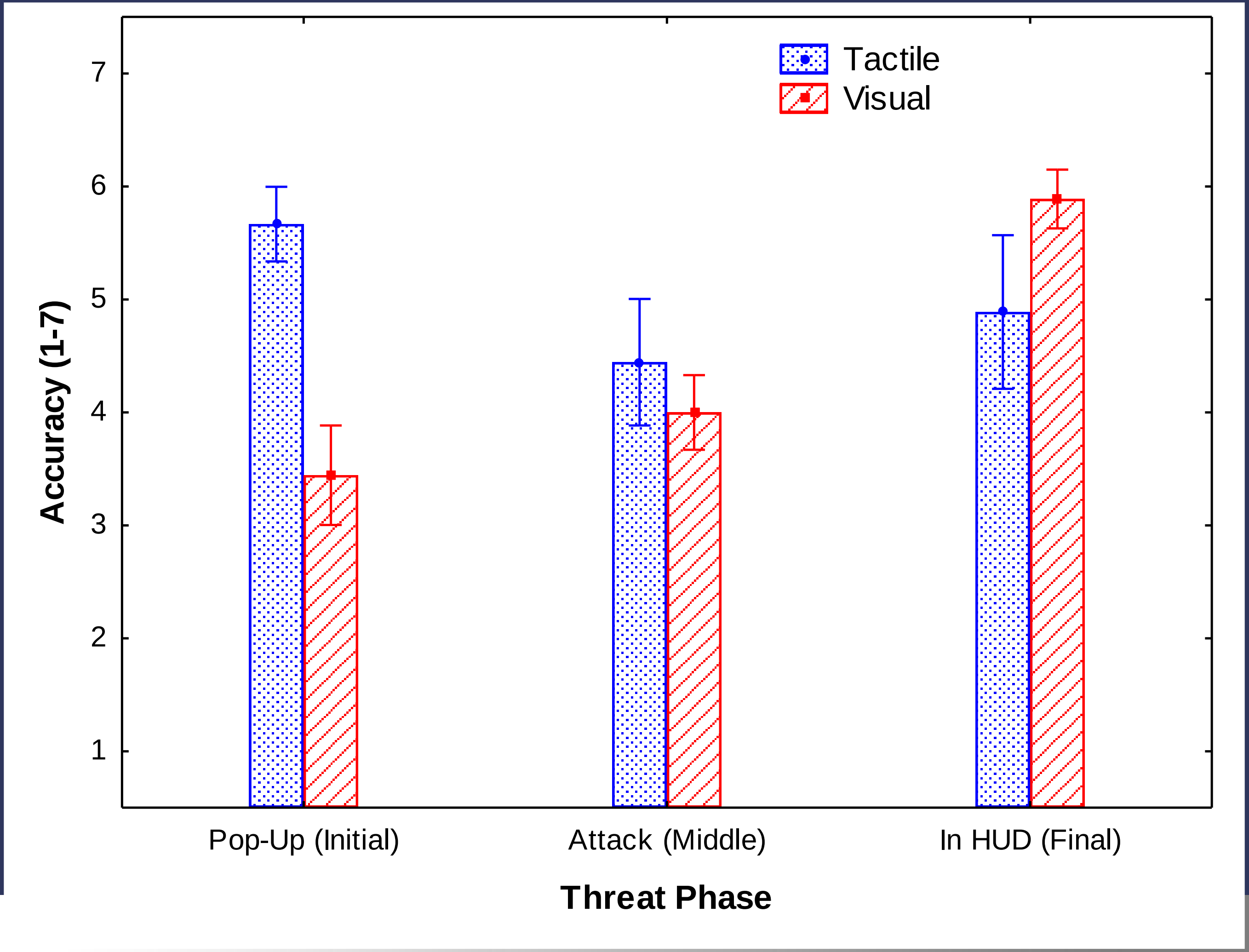
Total chase time: from threat pop-up to threat in centre of HUD

About 1 s faster with tactile vest for threats appearing from behind



Some results

Did you experience a clear threat position?
1=not at all   7=very clear



Conclusions

- High G-loads did not affect the tactile vest equipment
- Tactile cues possible to perceive and use at high G-loads
- Tactile: Faster initial response to targets
- Tactile: 1 s faster in mean chase time for targets behind
- Visual and tactile displays are complementary:
  - Tactile best for initial phase and for targets behind
  - Visual best for final phase requiring high spatial resolution

Tactile Cueing Works in Fighter Aircraft!

Questions?

Enhanced perception and performance by multimodal threat cueing in simulated combat vehicle

Oskarsson, Eriksson & Carlander

Human Factors 2012

Enhanced Perception and Performance by Multimodal Threat Cueing in Simulated Combat Vehicle

Per-Anders Oskarsson, Swedish Defence Research Agency, Linköping, Sweden, **Lars Eriksson**, Swedish National Road and Transport Research Institute, Linköping, Sweden, and **Otto Carlander**, Motorola Mobility, Linköping, Sweden

Objective: In a simulated combat vehicle, uni-, bi-, and trimodal cueing of direction to threat were compared with the purpose to investigate whether multisensory redundant information may enhance dynamic perception and performance.

Background: Previous research has shown that multimodal display presentation can enhance perception of information and task performance.

Method: Two experiments in a simulated combat vehicle were performed under the instructions to turn the vehicle toward the threat as fast and accurately as possible after threat cue onset. In Experiment 1, direction to threat was presented by four display types: visual head-down display, tactile belt, 3-D audio, and trimodal with the three displays combined. In Experiment 2, direction to threat was presented by three display types: visual head-up display (HUD)–3-D audio, tactile belt–3-D audio, and trimodal with HUD, tactile belt, and 3-D audio combined.

Results: In Experiment 1, the trimodal display provided overall best performance and perception of threat direction. In Experiment 2, both the trimodal and HUD–3-D audio displays led to overall best performance, and the trimodal display provided overall the best perception of threat direction. None of the trimodal displays induced higher mental workload or secondary task interference.

Conclusion: The trimodal displays provided overall enhanced perception and performance in the dynamically framed threat scenario and did not entail higher mental workload or decreased spare capacity.

Application: Trimodal displays with redundant information may contribute to safer and more reliable peak performance in time-critical dynamic tasks and especially in more extreme and stressful situations with high perceptual or mental workload.

Keywords: trimodal display, bimodal display, multimodal, threat cueing, tactile display, 3-D audio, visual display, perception and performance

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INTRODUCTION

Fundamental to multisensory information is the information redundancy we frequently and unconsciously process and capitalize on in our natural perception and action (e.g., Ernst & Bülthoff, 2004). Multisensory information that is complementary or redundant can improve detection and alerting effects (e.g., Spence & Driver, 2004), and multisensory displays may therefore support and improve operator perception and performance (Ho & Spence, 2008). There is in essence a need for further empirical studies on multisensory or multimodal processing in ecologically relevant situations, which include the interplay between endogenous (top-down) and exogenous (bottom-up) attention control, to realize the full potential of multimodal display interface design (e.g., Sarter, 2006, 2007; Spence & Ho, 2008). Although further empirical studies are needed, guiding principles for multimodal information in dynamic operator tasks are provided by multiple resource theory (Wickens, 1984, 2008; Wickens & Hollands, 2000). It suggests that we have several independent resources for processing of information but that some resources are more suited for simultaneous use (parallel processing) than others (sequential processing). That is, tasks using compatible resources that allow parallel processing may usually be performed simultaneously. Intramodal competition of resources within one modality may however cause interference, which may significantly deteriorate performance if one modality handles more than one task (e.g., simultaneous handling of two auditory tasks).

Santangelo and Spence (2007) performed experiments with unimodal auditory and visual cueing, respectively, and bimodal audiovisual cueing of peripheral visual targets. Better

Bakgrund

Multimodal eller multisensorisk information

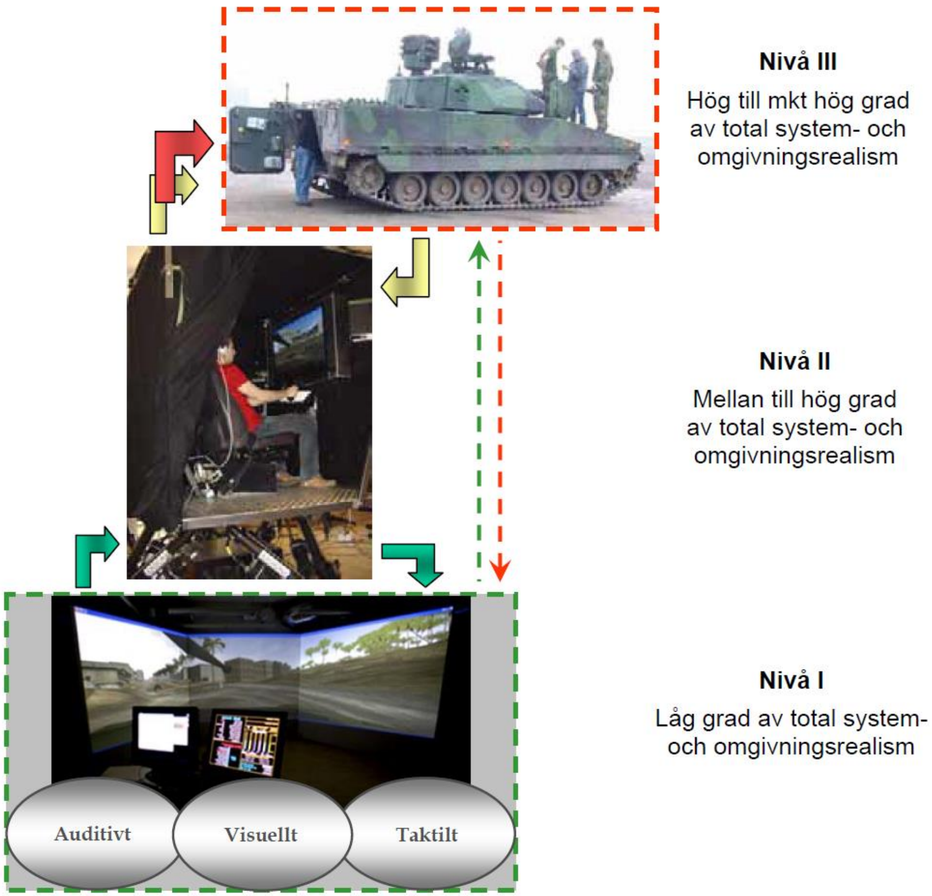
Tidigare forskning har i olika sammanhang visat att ***bimodala displayer*** kan ***förstärka/förbättra***:

- **Perception av information**
- **Uppgiftsprestation**

Frågeställning

Kan trimodal display förstärka/förbättra dynamisk perception & prestation i simulerat stridsfordon?

Metod

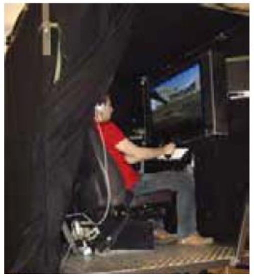


Grundscenario

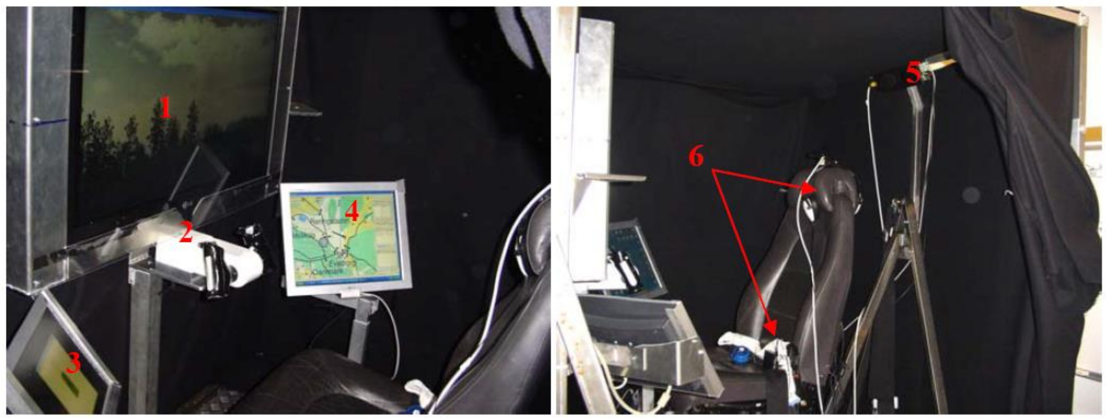
- Framföra fordonet
- Identifiera radioanrop
- Svänga snabbt in mot hot
- Bekämpa

Metod

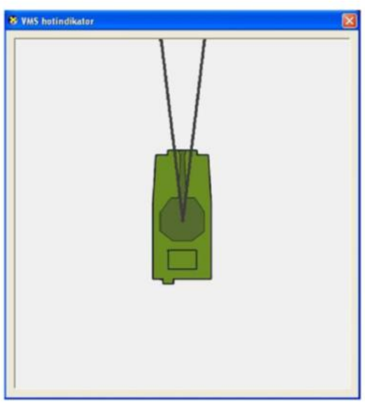
Experiment 1



- 12 deltagare (”naiva”)
- Män 21-29 år
- Moog 6DOF200E rörelseplattform + FOI simuleringsmotor
- Omvärldsutblick plasmaskärm



Figur 3. Operatörsmiljön anpassad för Strf90 med (1) omvärldsutblick, (2) styrdon, (3) hotinformation, (4) pekskärm, (5) head-tracker, och (6) 3D audio och taktilt bälte för auditiv resp. taktilt displaygränssnitt.



Hotindikering med

- **Taktilt bälte** 30° positioner = 12 taktorer (”klocklägen”)
- **3D-audio** med head-tracker
- **Head-down display (HDD)** LCD-display
- **Trimodalt**

Metod

Experiment 1

TABLE 1: The Four Types of Display Conditions With Type of Threat Cueing, Sound Alert, and Radio Calls

Display	Threat Direction Cueing	Sound Alert	Radio Calls
HDD	HDD	Mono sound	Mono sound
Tactile	Tactile belt	Mono sound	Mono sound
3-D audio	3-D audio	3-D audio	3-D audio
Trimodal	HDD + tactile belt + 3-D audio	3-D audio	3-D audio

Note. HDD = head-down display.

Hotindikering med

- **Taktilt bälte** 30° positioner = 12 taktorer (”klocklägen”)
- **3D-audio** med head-tracker
- **Head-down display (HDD)** LCD-display
- **Trimodalt**

Varje deltagare: Fyra blocks of trials x 24 hot = 96 hot

Huvudresultat

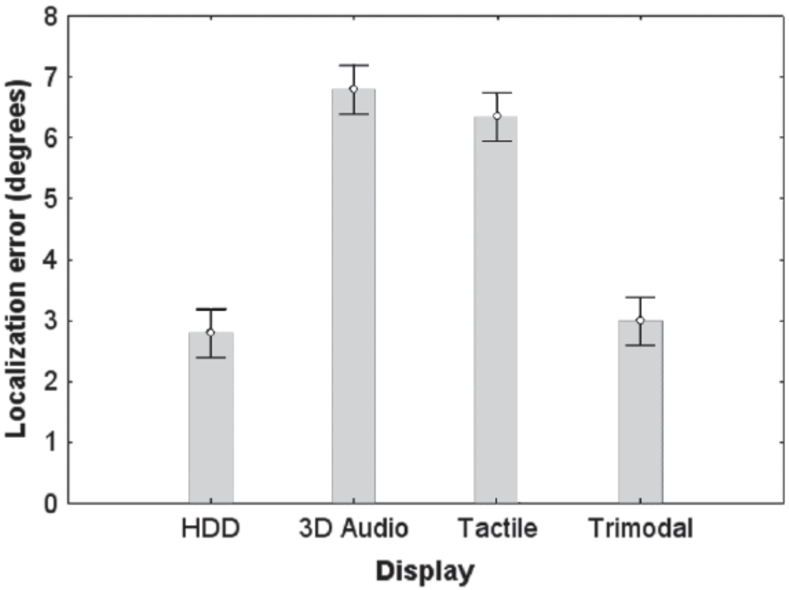


Figure 2. Mean localization error with each display configuration. Error bars = ±1 standard error; HDD = head-down display.

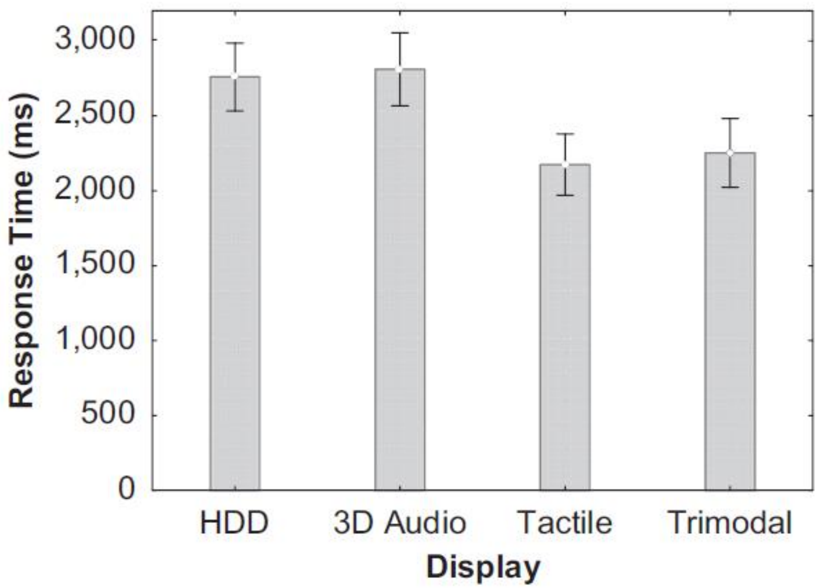


Figure 3. Mean threat response time with each display configuration. Error bars = ±1 standard error; HDD = head-down display.

Huvudresultat

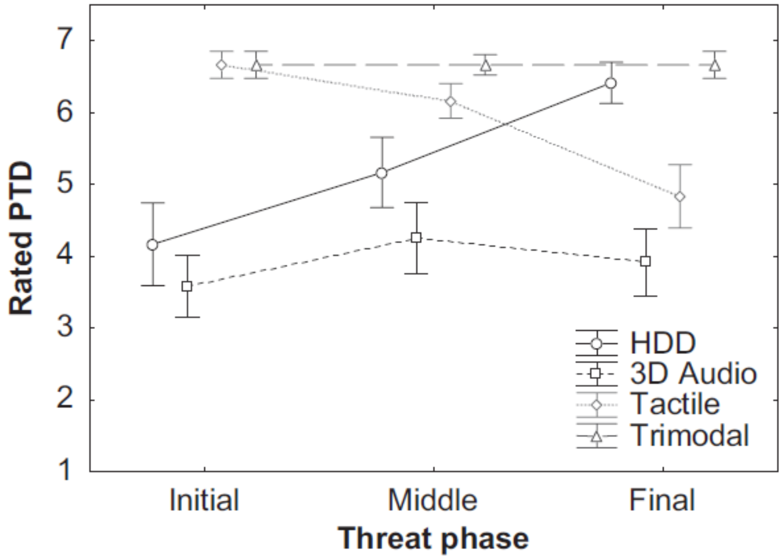


Figure 4. Perception of threat direction (PTD) for the four display types at threat cue onset (initial), maneuvering toward threat (middle), and aligning vehicle with threat (final). Error bars = ±1 standard error; HDD = head-down display.

Slutsatser

- **Trimodal hotindikering:**
  - Bättre precision än taktilt resp. 3D-audio
  - Kortare RT än HDD resp. 3D-audio
  - Bästa overall perception av hotriktning
  - Ej ökad mental belastning
  - Ej interferens med körning
  - Ej interferens med identifiering av radioanrop

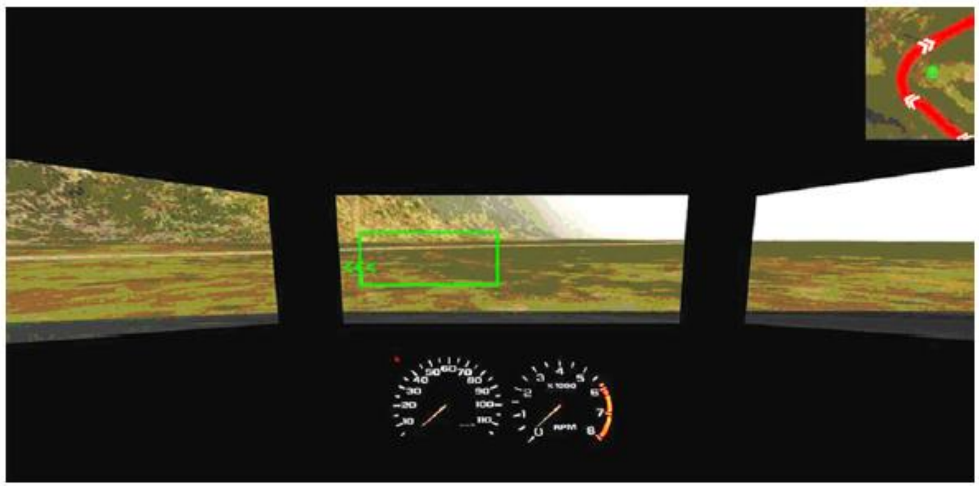
Frågeställningssvar

Trimodal display kan förstärka/förbättra dynamisk perception & prestation i simulerat stridsfordon!

Metod

Experiment 2

- 12 deltagare (”naiva”)
- 5 kvinnor & 7 män 21-34 år
- Moog 6DOF200E rörelseplattform + FOI simuleringsmotor
- Omvärldsutblick plasmaskärm



Hotindikering med

- **HUD-3D-audio**
- **Taktilt-3D-audio**
- **Trimodalt**

Varje deltagare: Tre blocks of trials x 24 hot = 72 hot

Metod

Experiment 2

TABLE 2: The Three Display Conditions With Type of Threat Cueing and Modality for Radio Calls

Display	Threat Direction Cueing and Sound Alert	Radio Calls
HUD–3-D audio	HUD + 3-D audio	3-D audio
Tactile–3-D audio	Tactile belt + 3-D audio	3-D audio
Trimodal	HUD + tactile belt + 3-D audio	3-D audio

Note. HUD = head-up display.

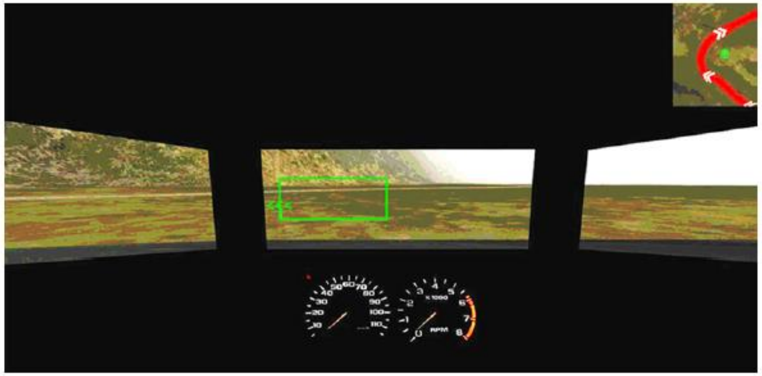


Figure 5. The simulated combat vehicle and surrounding terrain as viewed from driver position. The head-up display symbology in the center consisting of a rectangle and arrows indicates a threat to the left of the vehicle.

Huvudresultat

RT

Tactile – 3D-audio:	1987 ms
HUD – 3D-audio:	1682 ms
Trimodal:	1712 ms

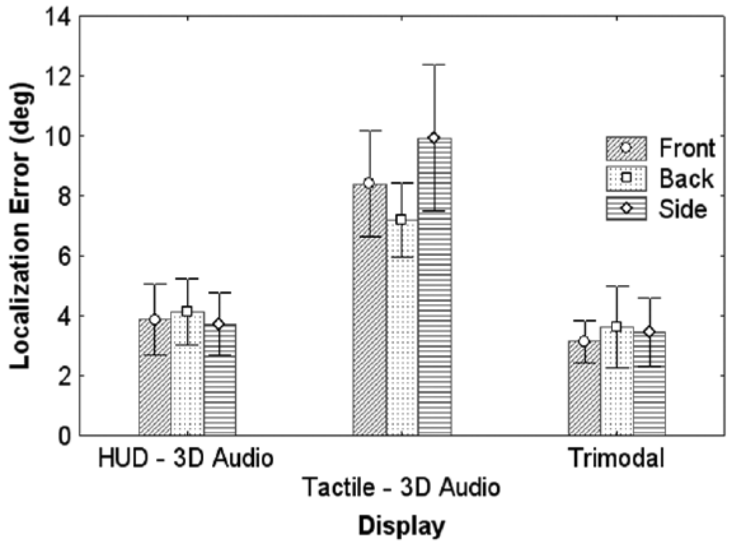


Figure 6. Mean localization error with each type of display configuration. Error bars = ±1 standard error; HUD = head-up display.

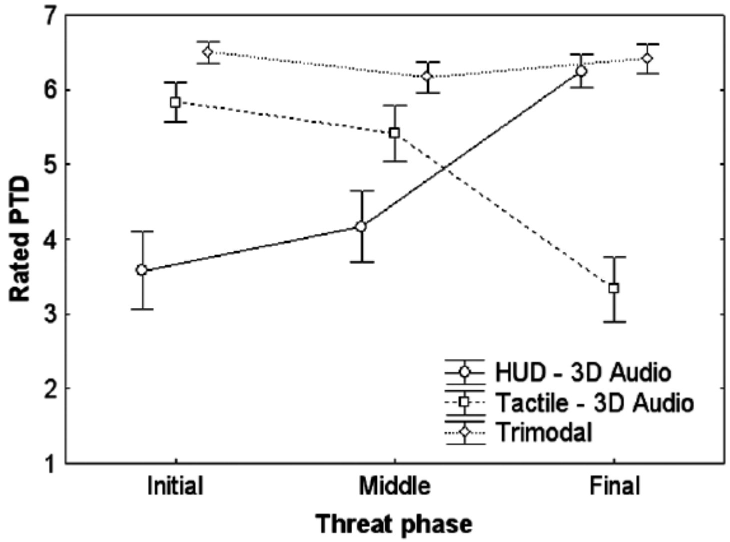


Figure 7. Perception of threat direction (PTD) for the three display types at threat cue onset (initial), maneuvering toward threat (middle), and aligning vehicle with threat (final). Error bars = ±1 standard error; HUD = head-up display.

Slutsatser

- **Trimodal hotindikering:**
  - Likvärdig precision med HUD-3D-audio
  - Likvärdig RT med HUD-3D-audio
  - Bästa overall perception av hotriktning
  - Ej ökad mental belastning
  - Ej interferens med körning
  - Ej interferens med identifiering av radioanrop

Frågeställningssvar

Trimodal display kan förstärka/förbättra dynamisk perception & prestation i simulerat stridsfordon!

Bimodala HUD-3D-audio var nära nog likvärdig overall!

Summering Experiment 1 & 2

TABLE 3: Summary of Group Means of the Measures for the Displays in Each Experiment

		Measure							
Exp.	Display	LE	RT	PCR	PTD Initial	PTD Middle	PTD Final	MW	ED
1	HDD	2.8*	2,759	.85	4.2	5.2	6.4*	3.8	2.3
	3-D audio	6.8	2,810	.81	3.6	4.3	3.9	4.4	2.3
	Tactile	6.3	2,175*	.82	6.7*	6.2	4.8	4.0	2.1
	Trimodal	3.0*	2,253*	.85	6.7*	6.7*	6.7*	3.8	2.3
2	HUD – 3-D audio	3.9*	1,682*	.85	3.6	4.2	6.3*	4.1	2.0
	Tactile – 3-D audio	8.5	1,987	.74	5.8*	5.4	3.3	3.6	2.3
	Trimodal	3.4*	1,712*	.79	6.5*	6.2*	6.4*	4.1	1.8

Note. LE = localization error (degrees); RT = response time (ms); PCR = proportion of correct radio calls; PTD = perception of threat direction; MW = mental workload; ED = effort of driving (subjective ratings, scale = 1–7); HDD = head-down display; HUD = head-up display.

*Indicates significantly best display configuration(s) for each measure within each experiment.

Age, cognitive load, and multimodal effects on driver response to directional warning

Lundqvist & Eriksson

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Age, cognitive load, and multimodal effects on driver response to directional warning

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ARTICLE INFO

Keywords:
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ABSTRACT

Inattention can be considered a primary cause of vehicular accidents or crashes, and in-car warning signals are applied to alert the driver to take action even in automated vehicles. Because of age related decline of the older driver's abilities, in-car warning signals may need adjustment to the older driver. We therefore investigated the effects of uni-, bi- and trimodal directional warnings (i.e., light, sound, vibration) on young and older drivers' responses in a driving simulator. A young group of 15 drivers (20–25 years of age) and an older group of 16 drivers (65–79 years of age) participated. In the simulations, warning signal was presented at the left, the center, or the right in front of the participant. With a warning at the left, the center, and the right the correct response was to steer to the right, brake, and steer to the left, respectively. The main results showed the older drivers' responses were slower for each type of warning compared with the young drivers' responses. Overall, the responses were slower with an added cognitively loading task. The only multimodal type of warning inducing overall faster response than its constituent warning types was the vibration-sound, and only for the older drivers. Additionally, with the groups' responses collapsed, such a true multimodal effect on response time also showed for the center vibration-sound warning (i.e., braking response). The only multimodal warning showing clear reduction in response errors compared with its constituent warning types was the vibration-sound for the older drivers during extra cognitive load. The main conclusion is that older drivers can benefit from bimodal warning, as compared with unimodal, in terms of faster and more accurate response. The potential superiority of trimodal warning is nevertheless argued.

1. Introduction

Safe car driving requires appropriate use of finite perceptual and cognitive resources, and inattention is considered a primary cause of vehicular accidents or crashes (e.g., Bärgman et al., 2015; Klauer et al., 2014; Victor, 2011). In-car warning signals can be applied to alert the driver of impending danger, such as with a switched-on red light in front of the driver just below the windshield on the dashboard to warn for a coming head-on collision. There also is a continued need for effective warning signals for some time regardless of whether the future driver will supervise or remain in full control of the car (De Winter et al., 2014; Lu et al., 2016). For example, the study by Petermeijer et al. (2017) underlines the need for a highly automated vehicle to provide an effective take-over request (TOR) when its operational limits are reached, which requires some warning signal that is reliably effective. The demand on perceptual and cognitive resources can though be extra challenging to the older driver because the perceptual, cognitive, and motor abilities normally decline with aging (Collins McLaughlin and Mayhorn, 2014; Dieuleveult et al., 2017; Freiherr et al., 2013; Thompson et al., 2012). Additionally, *"both the proportion and absolute number of older people in populations around the world are increasing dramatically"* (World Health Organization, 2015, p. 43), which essentially means an increase of older drivers (i.e., if they retain their license and continue driving). This in conjunction with the driver inattention problem may pose a growing safety issue, and in-car warning signals may need adjustment to the older driver's capabilities (Aksan et al., 2013; Cicchino and McCartt, 2015; Horberry et al., 2006; Laurienti et al., 2006).

Non-driving secondary tasks cause extra load that delay the driver's responses (e.g., Lee et al., 2009), and it has been estimated that over 30% of serious crashes are associated with the driver's engagement in some sort of secondary task (McEvoy et al., 2007). Staubach (2009) also reveals that distraction leads to a number of types of crashes, including those occurring at crossroads and in lane departures. The study by Young et al. (2013), for example, indicates which driver errors are more likely during distraction, and some of the reported high-criticality

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Bakgrund

Multimodal eller multisensorisk information

Ouppmärksamhet är en viktig orsak till bilolyckor

T o m automatiserade bilar har varningssignaler

Medelåldern för bilförare ökar globalt … ökad ålder → ökad säkerhetsrisk

Tidigare forskning har visat att ***bimodala displayer och även trimodala*** kan ***förstärka/förbättra***:

- **Perception av information**
- **Uppgiftsprestation**

Frågeställningar

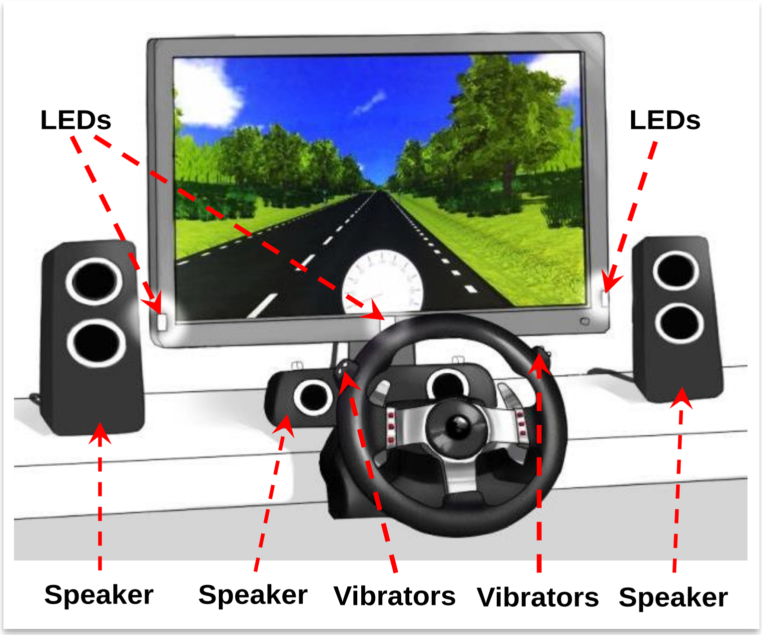
Kan multimodala varningar förstärka/förbättra perception & prestation i simulerat bilfordon?

Är äldre mer behjälpta av multimodala varningar?

Metod

Experimentdesign:
7 (Varningstyp) × 2 (Åldersgrupp) × 2 (Mental belastning) × 3 (Varningsriktning) factorial mixed

- 15 yngre förare 20-25 år, 4 kvinnor& 11 män
- 16 äldre förare 65-79 år, 8 kvinnor & 8 män
- Kau-byggd bilsimulator …



Uppgift: Hålla en hastighet på 80 km/h och respondera så snabbt som möjligt på varning från vänster, mitten och höger genom att styra till höger, bromsa resp. styra till vänster

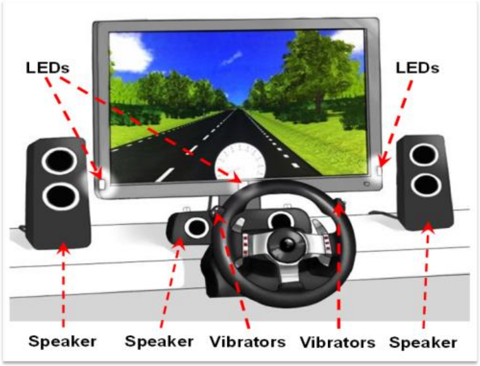
Metod

Unimodala varningar: Ljus, Ljud, Vibration

Bimodala varningar: Ljus/Ljud, Ljus/Vibration, Vibration/Ljud

Trimodal varning: Ljus/Vibration/Ljud

Varningsriktningar: Vänster, Mitten, Höger
Temporal & spatial synkronisering …

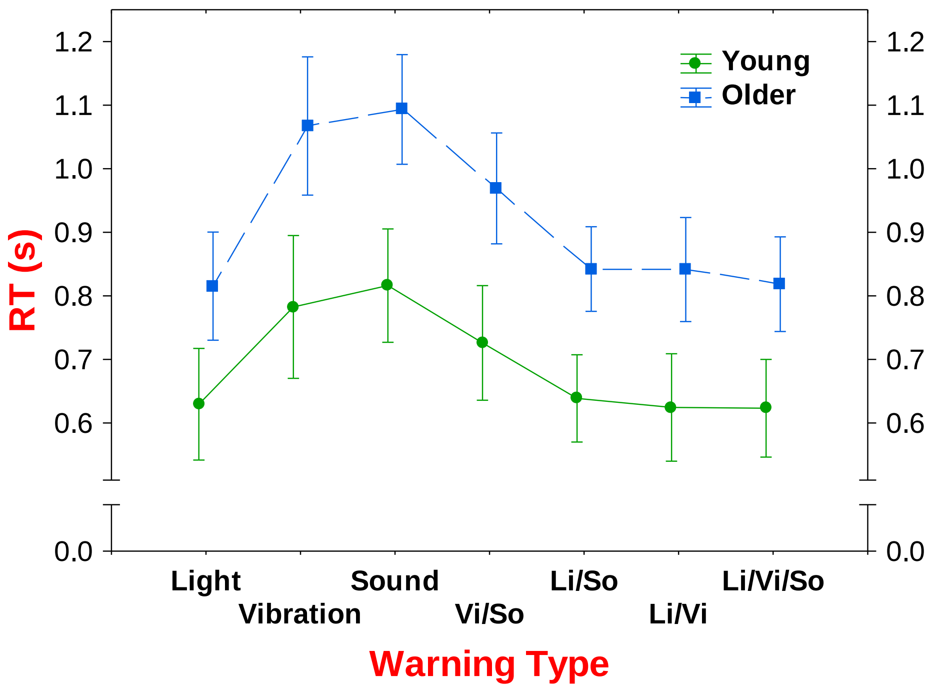


Mental belastning: Med/utan sekundäruppgift att räkna ner i steg om två från 1000

Varje förare utförde 14 blocks of trials:

1) De sju varningstyperna utan räkneuppgiften – 9x7 = 63 varningar
2) De sju varningstyperna med räkneuppgiften – 9x7 = 63 varningar

Huvudresultat



Frekvenser av responsfel (procent inom parentes).
Load = nedräkningsuppgiften.

	Young drivers		Older drivers	
Warning type	**No load**	**Load**	**No load**	**Load**
Light	1 (0.7)	2 (1.5)	1 (0.7)	3 (2.1)
Vibration	2 (1.5)	6 (4.4)	15 (10.4)	21 (14.6)
Sound	4 (3.0)	6 (4.4)	9 (6.2)	18 (12.5)
Vibration/Sound	2 (1.5)	2 (1.5)	8 (5.6)	6 (4.2)
Light/Sound	0 (0.0)	1 (0.7)	1 (0.7)	6 (4.2)
Light/Vibration	1 (0.7)	0 (0.0)	1 (0.7)	2 (1.4)
Light/Vibration/Sound	2 (1.5)	2 (1.5)	1 (0.7)	3 (2.1)

Huvudresultat/Slutsatser

- *Overall slower response during extra cognitive load*
- *Young drivers respond faster with each warning type*
- *Greatest differences between young and older drivers for sound alone, vibration alone, and combined sound/vibration*
- *Response overall faster for warnings including the visual cue than those that do not*
- *The only multisensory warning inducing faster response than all its constituent unisensory warning types is the bisensory vibration/sound, and only for older drivers*
- *Least response errors: Warnings including the visual cue*
- *Most response errors: Made by the older drivers with the unisensory sound and vibration during extra cognitive load, which is clearly mitigated by corresponding multisensory warning (vibration/sound)*

Frågeställningssvar

Multimodala varningar kan förstärka/förbättra perception & prestation i simulerat bilfordon!

Äldre har färre fel och är snabbare med bimodal varning

Ljusvarning effektiv unimodalt, bimodalt, trimodalt ≈ mörklagt rum → tydlighet

Slutsatser

Tillägg

Trimodala varningar har potential att vara
overall mest fördelaktiga i varierade miljöer
… såsom i starkt ljus & vid höga ljudnivåer & mkt vibrationer …

A systematic review of the neural correlates of multisensory integration in schizophrenia

Gröhn, Norgren & Eriksson

Schizophrenia Research: Cognition 2022

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Research Paper

A systematic review of the neural correlates of multisensory integration in schizophrenia

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ARTICLE INFO

Keywords:
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fMRI
EEG
Neural correlates
Multimodal perception

ABSTRACT

Multisensory integration (MSI), in which sensory signals from different modalities are unified, is necessary for our comprehensive perception of and effective adaptation to the objects and events around us. However, individuals with schizophrenia suffer from impairments in MSI, which could explain typical symptoms like hallucination and reality distortion. Because the neural correlates of aberrant MSI in schizophrenia help us understand the physiognomy of this psychiatric disorder, we performed a systematic review of the current research on this subject. The literature search concerned investigated MSI in diagnosed schizophrenia patients compared to healthy controls using brain imaging. Seventeen of 317 identified studies were finally included. To assess risk of bias, the Newcastle-Ottawa quality assessment was used, and the review was written according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA). The results indicated that multisensory processes in schizophrenia are associated with aberrant, mainly reduced, neural activity in several brain regions, as measured by event-related potentials, oscillations, activity and connectivity. The conclusion is that a fronto-temporal region, comprising the frontal inferior gyrus, middle temporal gyrus and superior temporal gyrus/sulcus, along with the fusiform gyrus and dorsal visual stream in the occipital-parietal lobe are possible key regions of deficient MSI in schizophrenia.

1. Introduction

We constantly encounter an abundance of sensory information that has to be successfully organized for us to be able to make sense of it. The converging processes of sensory modalities (e.g., auditory, visual, tactile modalities) required to generate a meaningful and coherent perception underlie the concept of multisensory integration (MSI; Talsma et al., 2010). For example, during a conversation with a friend in a busy restaurant, you will perceptually process your friend's voice (i.e., auditory stimuli) and articulations (i.e., visual stimuli) concurrently and rapidly to integrate them. This integration will increase your speech perception because MSI enhances perceptual acuity and improves detection, discrimination and response speed (Wallace et al., 2020). MSI does not only help us avoid cognitive overload and create meaning in the constant sensory information flood (Jensen et al., 2019), but also plays a crucial role for our daily functioning and well-being through guiding our responses to the complex outer world (Tseng et al., 2015).

Different types of research paradigms have been used to study the effects of MSI on behavior. Some focus on multisensory illusions that show how information from different sensory modalities can fuse together into one percept. One example is the *McGurk effect* in which a video of a person saying one phoneme (e.g., 'ga') is dubbed with a recording of another phoneme (e.g., 'ba') and resulting in the perceived illusion of a mixed phoneme (e.g., 'da') (McGurk & MacDonald, 1976). Other studies focus on the performance enhancement multisensory stimuli enable. One example is the redundant signals effect (RSE), which shows that responses are faster and more precise with stimuli presented in multiple sensory modalities compared to a single modality (Hershenson, 1962; Kinchla, 1974). Groundbreaking electrophysiology studies of neurons in the superior colliculus discovered important principles for MSI (Meredith and Stein, 1983, 1986; Stein and Stanford, 2008). According to the principle of inverse effectiveness, multisensory enhancement is greater if the unisensory signals are of low intensity. In addition, multisensory facilitation is maximal when stimuli from different modalities are presented at the same time (temporal rule) at around the same place (spatial rule), and decreases with increased inter-stimulus onset (Stone et al., 2014).

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Bakgrund

Multisensorisk integration (MSI)

- organisera sinnesinformation
- undvika kognitiv överbelastning
- guida responser på omvärlden bättre

Bimodal integration (”vanligast”)

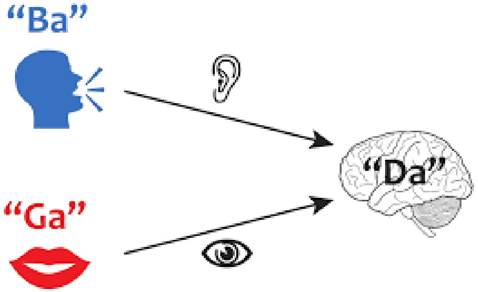
ex. ***höra* + *se*** den som talar i folksamlingssorl

förbättrar detektion, diskrimination, responstid

förbättrar taluppfattningen

Illusioner (”mekanismavslöjande”)

McGurk illusion (höra + se)



Rubber hand illusion (känna + se)

Bakgrund

Filmtajm!

McGurk illusion

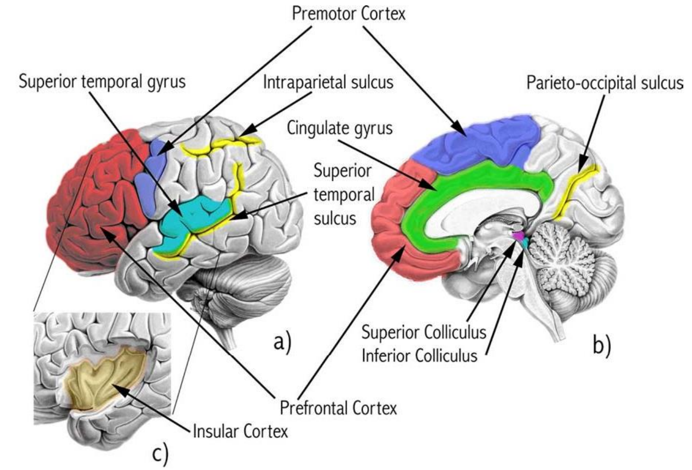
Bakgrund

Filmtajm!

Rubber hand illusion

Bakgrund

Multisensorisk integration (MSI)
Neurala korrelat



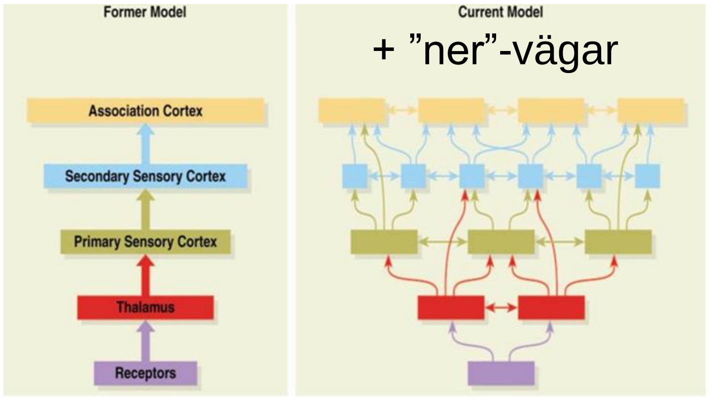
- *flera olika platser i hjärnan*
- *låg- och högnivå*
- *kopplingar emellan*
- *striatum, cerebellum, amygdala, thalamus*
- *intraparietal sulcus, premotor, prefrontal*
- *superior temporal sulcus (**STS**): tal, biologisk rörelse*

- ***STS**: bimodala + trimodala + undertröskliga neuron responderar på visuellt, auditivt, somatosensoriskt*

”Modernare” MSI-förklaring

- bottom-up + top-down
  + mellan modaliteter (prediktioner)
- **MSI → flexibelt & kontextberoende**

… förståelsen ändå inte särskilt stark



Bakgrund

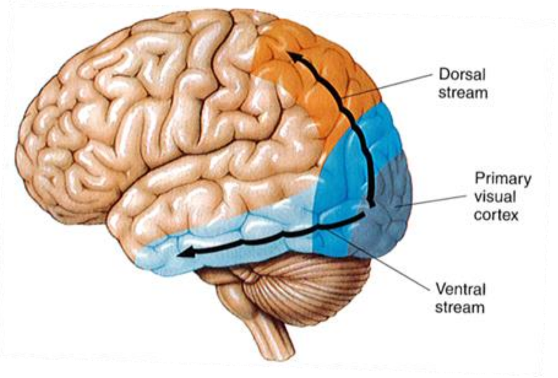
MSI & schizofreni

- Positiva symptom: hallucination & inbillning …
- Negativa Symptom: motivationslöshet & viljelöshet …
- motsvaras av brist i integration av visuellt, auditivt, taktilt …
- MSI-förstärkning mindre eller inte alls (ex. se & höra den talande)
- McGurk-effekt mer sällan (ej fusion)

… MEN finns motstridiga resultat …

Neurala korrelat

- många hjärnregioner uppvisar abnormalitet …
- bl.a. hippocampus, amygdala, superior temporal gyrus (STG), visuellt dorsala strömmen (vision for action)
- m.fl. …



Metod

Inklusion

- diagnosticerade schizofrena eller schizoaffektiva (ej annat)
- kontrollgrupp normala – *särskilt VIKTIGT p g a ”flex & kontext”*
- MSI: alla kombinationer av sinnesmodaliteter
- mätning med hjärnavbildande teknik (EEG, MEG, fMRI)

electroencephalography
magnetoencephalography
functional magnetic resonance imaging

- peer-reviewed engelska tidskriftsartiklar

Sökstrategi & selektionsprocess

- enligt PRISMA
- databassökning: PsychInfo, PubMed, Web of Science
- två reviewers (3)

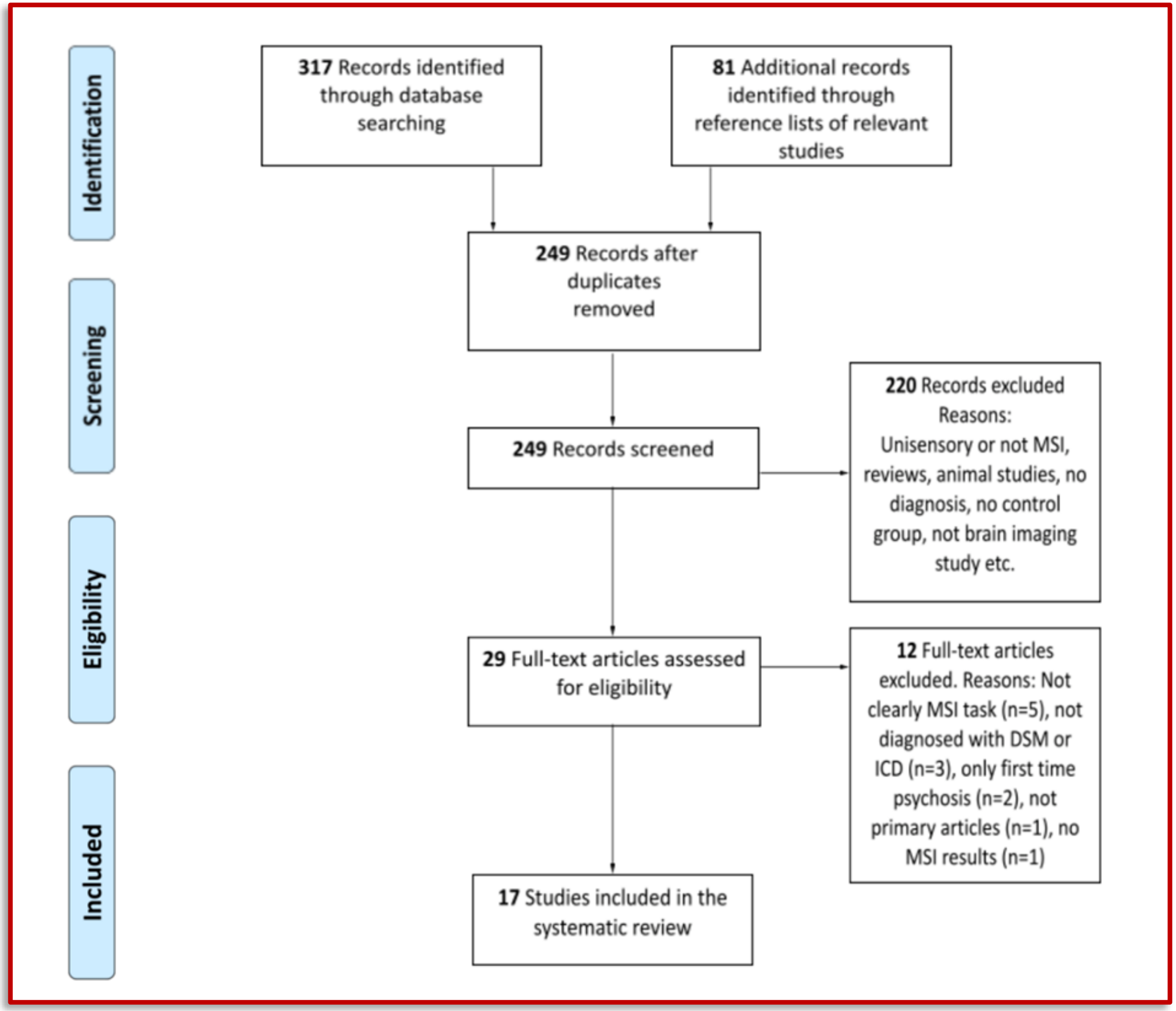
Metod

Kvalitetsbedömning

- enligt Newcastle-Ottawa Quality Assessment Scale (NOS)
- NOS: Urval (4), Jämförbarhet (2), Exponering (2)
- NOS: Minst 5 av 8 uppfyllda = OK

	Quality assessment criteria								
	Selection (4 stars)				Comparability (2 stars)		Exposure (2 stars)		
	Is the population definition adequate?	Representativeness of the population	Selection of controls	Definition of controls	Study controls for schizophrenia	Study controls for additional factor	Same method of ascertainment for cases and controls	Non-response rate	
Study	Schizophrenia or schizoaffective disorder according to DSM or ICD	Representative of the schizophrenia population	Same community	Healthy individuals with no current or	Diagnosed schizophrenia compared to healthy controls	Gender, age, education/ cognitive functioning (e.g., IQ)	Methods are identical	Same rate for both groups	Quality score (max. 8 stars)

Metod

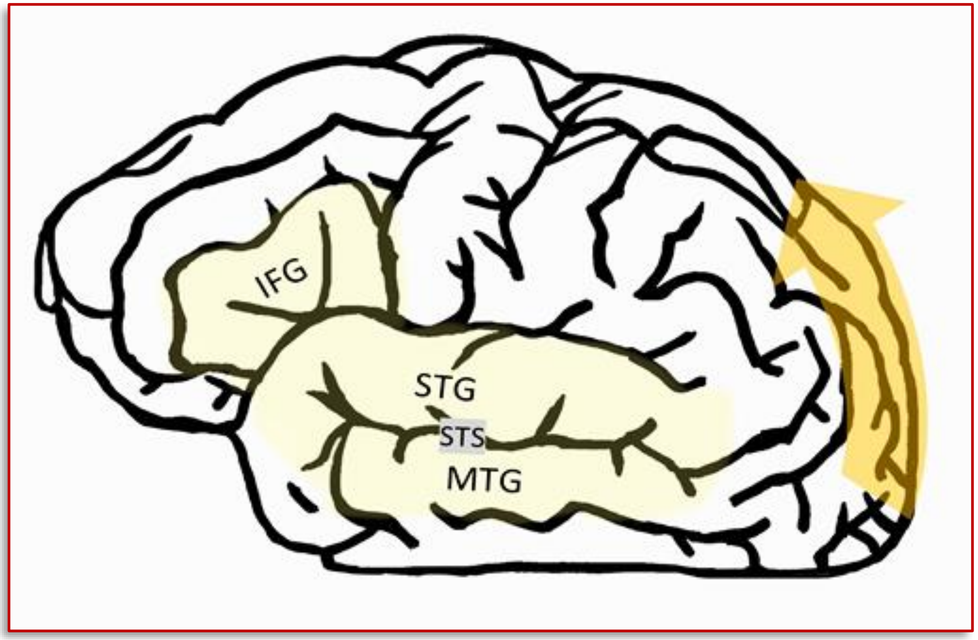


Alla 17 studier klarade minst 5 av 8 NOS-kriterier

Huvudresultat

NORMAL
n = 284

SCHIZO
n = 282



Huvudsakliga områden med MSI-processbrister hos SCHIZO

STS	superior temporal sulcus	*Många olika processer, multisensoriskt*
STG	superior temporal gyrus	*Ex. auditivt, social kognition*
MTG	middle temporal gyrus	*Ex. semantiskt minne, språk*
IFG	inferior frontal gyrus	*Ex. tal, språk*
FG	fusiform gyrus (syns ej ovan)	*Ex. objekt- & ansiktsigenkänning*
Visuellt dorsala strömmen		*Vision for action ≈ visuellt + motorik*

Slutsatser/Diskussion

SLUTSATSER

(1) Aktiviteten i neurala MSI-korrelat är framförallt reducerad hos SCHIZO

(2) Distribuerat över flera hjärnområden & -nätverk för MSI-processer

(3) Inga klara samband mellan experimentell design, hjärnavbildningsteknik och neural aktivitet

Begränsningar & Reflektioner

- Begränsat stickprov artiklar … och *eller* men *n*=282 & *n*=284
- Heterogena studier: experimentdesign/experimentuppgift
- Schizofreni är heterogent ≈ olika grad av MSI-processbrist
- MSI-processbrist inte alltid reflekterat i prestationsmått!
  … Individers kompensering för MSI-brist bör studeras
- Endast visuell-auditiv-kombination i studierna
  … Andra sinneskombinationer bör studeras

Tack för mig!