Multimodal Display Rationale

High-workload, fast-paced, and degraded sensory environments (e.g., during EVA and teleoperated operations) are the likeliest to benefit from multimodal displays that can:
- Enhance situation awareness and task performance by maximizing the effectiveness of different sensory channels through appropriate interaction between modalities.
- Play an important role informing interface guidelines for long duration exploration missions (LDEMs) requiring greater crew autonomy with increased dependence on spacecraft information systems for both routine and time-critical tasks.

Benefits of Multimodal Displays
- Increased bandwidth: Increases the amount of information that can be processed over a fixed time period.
- Cognition: Enhancement of scene information in more than one sensory channel (e.g., auditory and visual).
- Quantitative improvement in information from different sensory channels is interpreted to add modality.
- Multimodal integration: Using sensory channels based on their suitability for presenting particular kinds of information (e.g., auditory suited for voice commands, alarms).
- Complementary: Presenting related information in different sensory channels to avoid being merged to form a unified perception of an object on an event.
- Substituting: Presenting information in an alternative modality when other sensory channels become temporarily or permanently unavailable.

Multisensory Integration

Evidence from both behavioral and neuroscience research demonstrates significant cross-modal links between visual, auditory, and touch.
- Modality-specific: Top-down influence on attention allocation.
- Observations: Information increases in the expected channel.
- Spatially: Top-down influence on attention allocation.
- Modality: Performance enhances when attention is enhanced from unimportant modality to an inherently used channel.
- RTs: Slowed for events in less frequent modalities.
- Cross-modal spatial links to enhanced facilitation of components when simultaneous stimuli are at the same location or in response suppression for stimuli at different locations if they are presented in time.
- Perfect spatial and temporal alignment is not required for multisensory integration to occur as long as the modalities are presented within close spatial and temporal proximity (e.g., as defined by psychophysical studies).

Literature Review: Applied Studies of Multimodal Displays

Multimodal display research covers:
- Often developed in a lab and not in an actual operating environment.
- Do not consider basic mechanisms of human multisensory integration and cross-modal attention.
- Equivalence between stimuli in each sensory channel (e.g., comparable detection thresholds) is rarely established prior to a study.
- Performance measures not always directly compared among all possible combinations of unimodal, bimodal, trimodal, or mixed modal displays.
- Clear inferences about relative multisensory benefits can be problematic.

Examples of Applied Studies of Multimodal Displays

- Multimodal displays can be seen in military and aviation displays (e.g., HUD displays). Performance varies depending on factors such as the spatial congruency of spatial tasks.
- Studies show multimodal displays produce different effects depending on workload, e.g., multimodal displays can become significantly more effective than unimodal displays for high workload, e.g., helicopter noise, and during air traffic control.

Adaptive Multimodal Information Displays

- User-adaptive break in the foreground: Fixed assignment of fixed industrial to tasks or types of information are not adaptable to user needs.
- Multimodal interfaces can accommodate possible changes in the needs, abilities, and experience levels of users depending on the type of tasks being performed, the environment, and the level of workload.
- Adaptive displays are designed specifically for detecting and presenting to user corollary information.
- Simple approaches based on user preference are ineffective in complex task environments, such as flight decks, where crew members require at least some degree of automation supported.

Multimodal Displays in Space Environments

- Although the effect of microgravity is not highly well documented for individual sensory systems, less is known about interactions between the senses.
- The normal contribution of sensory modalities to perceptual experience on Earth will not be relevant in space, since the reliability of the different senses may change. For example, the usual dominance of visual cues in multisensory perception may decrease, and the role of auditory and tactile cues may increase.
- Some conclusions may be drawn from analog studies or conditions mimicking microgravity.

Current Standards & Guidelines

- Surprisingly, few consistent guidance directly addressing multimodal displays is currently available in the form of standards and guidelines. There are several guidelines, but they vary considerably in terms of their specific focus and level of abstraction.
- Examples of general guidelines concerned with the effective combination and integration of sensory channels, but they are primarily based on research using binocular information and free direct vision (not beyond information presentation).
- NASA-3001 standards for crew interfaces are the highest level standards, with multimodal recommendations. However, in space, these standards tend to be at level two. Neither specifically address multimodal displays.

Examples of Current Standards & Guidelines

- MIL-HDBK-1525 (2008) International standards for multichannel design principles that focus on the impact of audio
- IEEE 810 (2015) develops a framework for developing and implementing multichannel display functions that include the safety and compatibility of multimodal displays.
- Human Factors Engineering (2006, 2013) that focuses on the effective use of visual, auditory, and tactile channels.
- MIL-STD-1472G (2012) DoD standard that provides a methodology for detecting and/or user-controlled adaptivity (user preference profiles).

Adaptivity discusses six categories of guidelines: Requirements, Design Criteria Standard: Human Engineering that provides a comprehensive and comprehensive standard for detecting and/or user-controlled adaptivity (user preference profiles).

Some conclusions may be drawn from other HIDH sections for guidelines that are specific to multimodal interface design or that focus on the choice of individual sensory channels for given tasks and environments.

Adaptability may be more general guidelines concerned with the effective use of sensory channels (e.g., auditory and tactile). Performance varies depending on factors such as the spatial congruency of spatial tasks.

Multimodal interfaces must accommodate possible changes in the needs, abilities, and experience levels of users depending on the type of tasks being performed, the environment, and the level of workload.

- Adaptive displays presuppose adequate methods are developed for detecting and/or user-controlled adaptivity (user preference profiles).
- Simple approaches based on user preference are not effective in complex task environments, such as flight decks, where crew members require at least some degree of automation supported.

Recommendations for NASA

- Incorporate multichannel (M) guidance into HID guidance levels that exceed highest level recommendations (this should be done for a number of critical areas in HID).
- More consistent guidance directly addressing multimodal displays as rarely well documented for individual sensory systems, less is known about interactions between the senses.
- The normal contribution of sensory modalities to perceptual experience on Earth will not be relevant in space, since the reliability of the different senses will change. For example, the usual dominance of visual cues in multisensory perception may decrease, and the role of auditory and tactile cues may increase.
- Some conclusions may be drawn from analog studies or conditions mimicking microgravity, but in space environment will remain suitable to Earth.

H-II Transfer Vehicle (HTV), Cupola and Berthing: Robotics Ground Controllers powered up the Station during the Space Station Power System (SSPSM), August 2013

References