Effects of time of day and cognitive load on aided performance

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A link among hearing loss, fatigue, listening effort, and cognitive drain has been suggested to impact benefit from amplification. Hornsby (2013) investigated the effects of hearing aid (HA) use on effort and fatigue for complex listening, suggesting that these negative consequences can be reduced by using well-fit HAs. To probe into this, an experiment was designed where 14 HA users were tested aided in complex listening tasks on late Friday afternoon, Saturday morning, and late Saturday afternoon. In between the two Saturday tests participants were taken on a tour, designed to span a range of challenging listening tasks. This was done twice, using two different levels of hearing technology. Single and dual task versions of the hearing in noise test (HINT) were used to test listening abilities. Self-report probed into fatigue and vigor, different aspects of perceived listening, and characterized participants as morning, intermediate, or evening types. In addition to audiometric measures, the reading span was used to assess cognitive status. Results showed that aided listening changed over the course of a day, performance in the morning was not the best despite most participants being morning types, and well-rested and speech understanding was better in the afternoon despite self-perceived fatigue being increased. Higher technology level did positively affect some objective and subjective listening abilities.

PURPOSE

The purpose of this study was to evaluate fatigue and cognitive effort using two different levels of HA signal processing technology at three different time points associated with a day of active listening activities.

METHODS

Participants

Fourteen experienced adult HA users (7 male; 7 female) ranging in age from 55-83 years (mean = 70; SD = 8.9) participated. Subjects met the following inclusion criteria:

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- ≥ 12 months of previous hearing aid use;
- Bilaterally symmetric sensorineural hearing loss within the fitting range of the test HAs (Fig. 1);
- Passed a vision screening assessment (ability to read aloud and comprehend a short passage printed with 12-point font); and
- Passed the Montreal Cognitive Assessment (Nasreddine *et al.*, 2005).

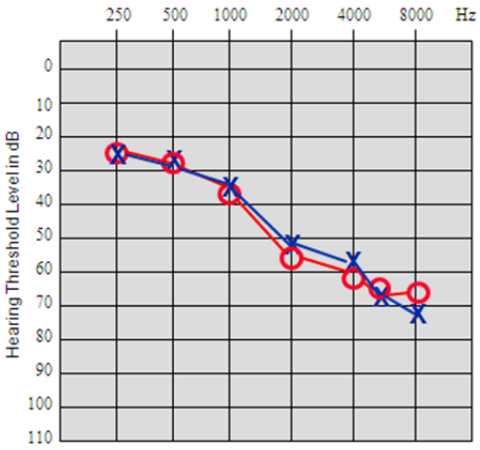

Fig. 1: Mean pure tone air conduction thresholds of the participants (n=14).

Laboratory measures: Objective testing

Hearing in Noise Test (HINT; Nilsson *et al.*, 1994): Listeners repeated sentences spoken by a male speaker in the presence of a fixed (70 dBA) competing noise in the sound field using the standard adaptive technique to determine the speech reception threshold (SRT). The HINT was administered under two conditions:

- HINT Single Task: The HINT was administered as an auditory task solely.
- HINT Dual Task: The HINT was administered along with a simultaneous visual task – the Pattern Completion Test (PCT; Pittman and Petersen, 2011) to assess cognitive effort.
- PCT: Various geometric symbols occurred in a row in a pattern of 2, 3, or 4 shapes and were presented on a computer monitor. A total of 11 symbols were presented and the subject was required to select which of 4 possible symbols would be the next symbol in the pattern.

Self-Report Questionnaires: Subjective Testing

Morningness-Eveningness Questionnaire (MEQ; Horn and Ostberg, 1976): 19-item questionnaire designed to assess whether a subject is more alert in the morning or

evening (e.g., *How alert do you feel during the first half hour you are awake in the morning?*). Scores range from 16 – 86 points:

< 41 points	evening types
42-58 points	intermediate types
> 59 points	morning types

Profile of Mood States (POMS; McNair *et al.*, 1971): 15-item questionnaire used to verify fatigue/vigor. Participants rated on a 5-point scale (0 = "not at all" to 4 = "extremely") how well the item related to his or her feelings at that time.

Effort Questionnaire: Six questions examining perceived listening effort, willingness or ability to compensate for the various listening environments, any changes in listening strategy during the day, and perceived physical fatigue were responded to by the participants using a 11-point scale with anchors for 0 and 10 as indicated in Table 1.

Question no.	Wording used	Anchors
1	How often did you find it hard to hear during the activity you just completed?	Never/All the time
2	Did you ever stop trying to hear?	Never/All the time
3	How often do you participate in an activity like this one?	Never/All the time
4	Do you feel tired from the effort you had to make to hear?	Not at all/Completely
5	Do you feel tired from the physical effort associated with the activity?	Not at all/Completely
6	Was the activity enjoyable?	Not at all/Completely

Table 1: Overview of questionnaire used to assess aspects of listening effort in the morning, in the afternoon and in the evening.

Test Devices

- Device HA 1: Oticon Alta Pro; premium level device
- Device HA 2: Oticon Nera Pro; midlevel device

PROCEDURES

The participant was fit with the test device approximately 7 days prior to the weekend activities allowing one-week acclimatization period. Participants were fit

binaurally with each set of devices counterbalancing which set was tested first. Programming of the devices followed standard clinical procedures. Verification of fit was performed using real ear measurement.

Each participant was tested three times within a 24-hour period per set of devices. These time-of-day (TOD) sessions occurred on Friday afternoon, Saturday morning, and Saturday afternoon. At each session, the POMS, HINT Single Task, and HINT Dual Task were administered. In between the Saturday morning and Saturday late afternoon experimental tests sessions, participants were taken as a group of 4-6 participants and spouses on a listening tour of local community sites/events designed to span a range of challenging listening situations. These included talking to other participants (previously unknown to each other) on the bus, at a busy mall and restaurant, during a tour at a museum, and other environments. These listening situations included various background noise and acoustical conditions, yet the situations were controlled across the participants. During the day's activities, the participants were asked to complete the Effort Questionnaire at three different time intervals (morning, noon, and afternoon).

The above test paradigm was repeated the following weekend for the other set of devices. To verify that both weekends offered very similar listening environments, a dosimeter was used to monitor each event. All weekends were found to be comparable.

RESULTS

The Morningness-Eveningness Questionnaire revealed that the majority of the participants were morning type as shown in Fig. 2.

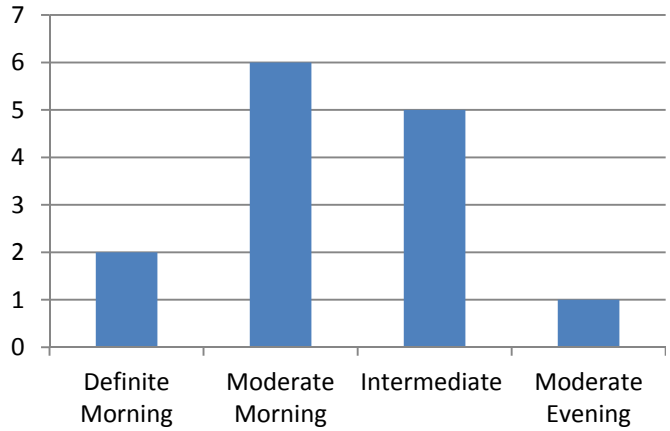

Fig. 2: Number of subjects who were categorized as a morning, intermediate, or evening type (n=14).

The HINT Single and Dual Tests performance was slightly better for the Saturday PM TOD. However, statistical significance was not reached as seen in Fig. 3.

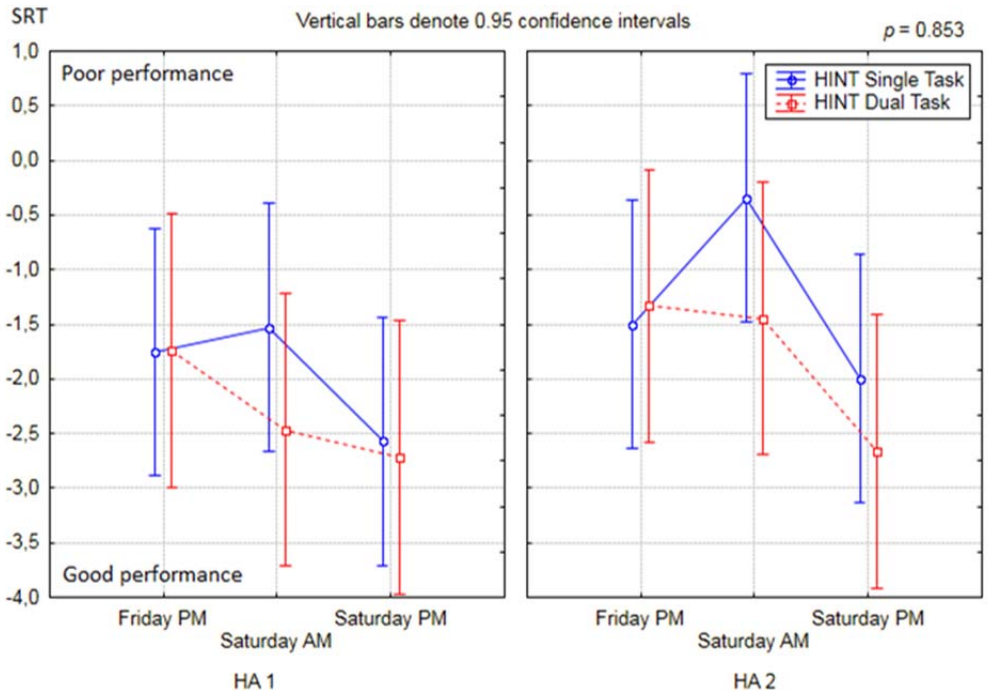

Fig. 3: Mean SRT for the HINT Tests across HA Level and Time of Day. Morning test time was abbreviated AM and afternoon test time was abbreviated PM.

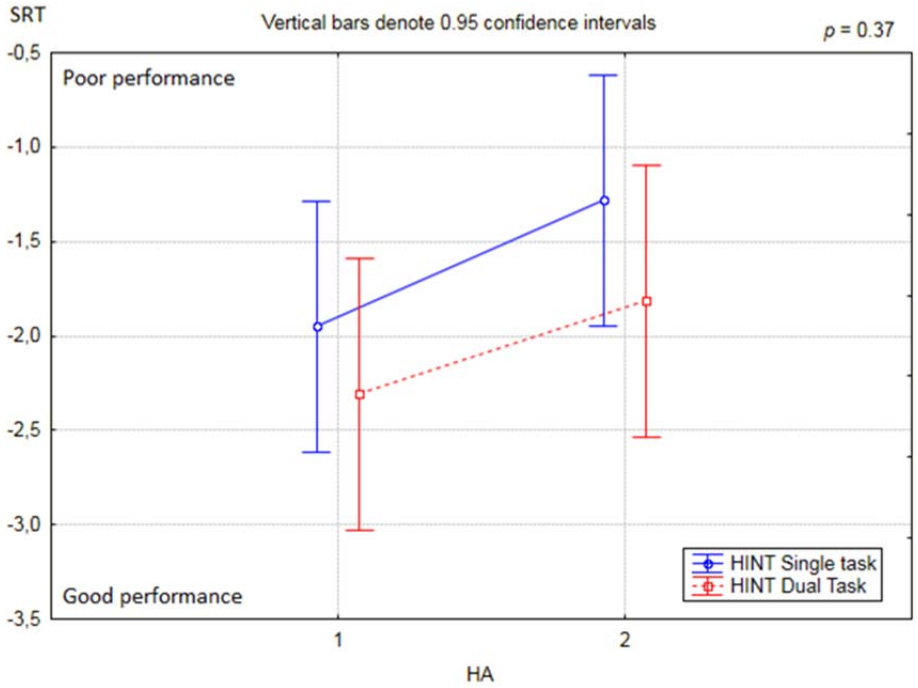

Fig. 4: The mean HINT SRTs for the Single and Dual Tasks across HA Level collapsing time of day.

Figure 4 illustrates the means for the HINT Single and Dual Tasks across the HA levels. Note that although the results are not statistically different, there is a trend showing performance on the Dual Task was better than the Single Task and that HA 1 was better than HA 2. Further, Killion *et al.* (2004) suggested that for every 1 dB of change in signal-to-noise ratio on the SRT there is an 11% change in speech intelligibility, so there may be clinical significance of these findings.

The POMS Scale Fatigue and Vigor results suggested that the participants maintained low fatigue and high vigor across the TOD as seen in Fig. 5.

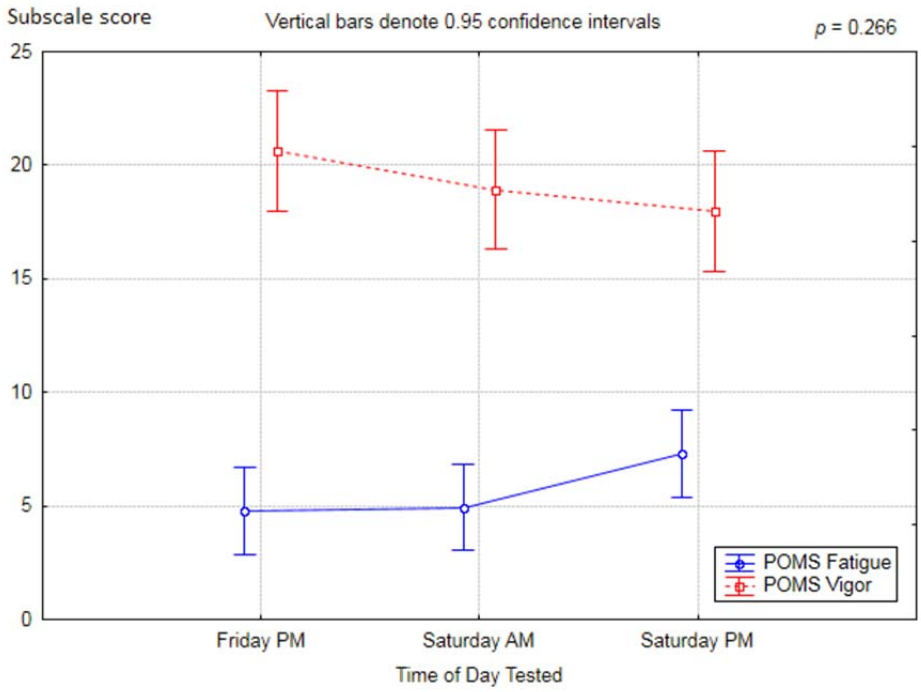

Fig. 5: Mean ratings for 2 subscales of the POMS. Total possible scores for the *Vigor* subscale is 32 points and for the *Fatigue* subscale is 28 points (n=14). Morning test time was abbreviated AM and afternoon test time was abbreviated PM.

Figure 6 illustrates the mean ratings for selected items from the Effort Questionnaire. Results suggest that overall, participants found listening effort, difficulty hearing, and the physical tiredness to be minimal while finding the day quite enjoyable.

Post hoc (Tukey HSD test, $p < 0.01$) revealed that:

- Within HA 1 – participants had less tiredness, effort and difficulty in the Saturday morning and Saturday afternoon compared to the Saturday noon testing;

- Within HA 2 – no statistical differences were found across the 3 Saturday assessment times (morning, noon, and afternoon); and
- Between HA/s – results from HA 1 were statistically better than the results from HA 2 for Saturday morning and Saturday afternoon.

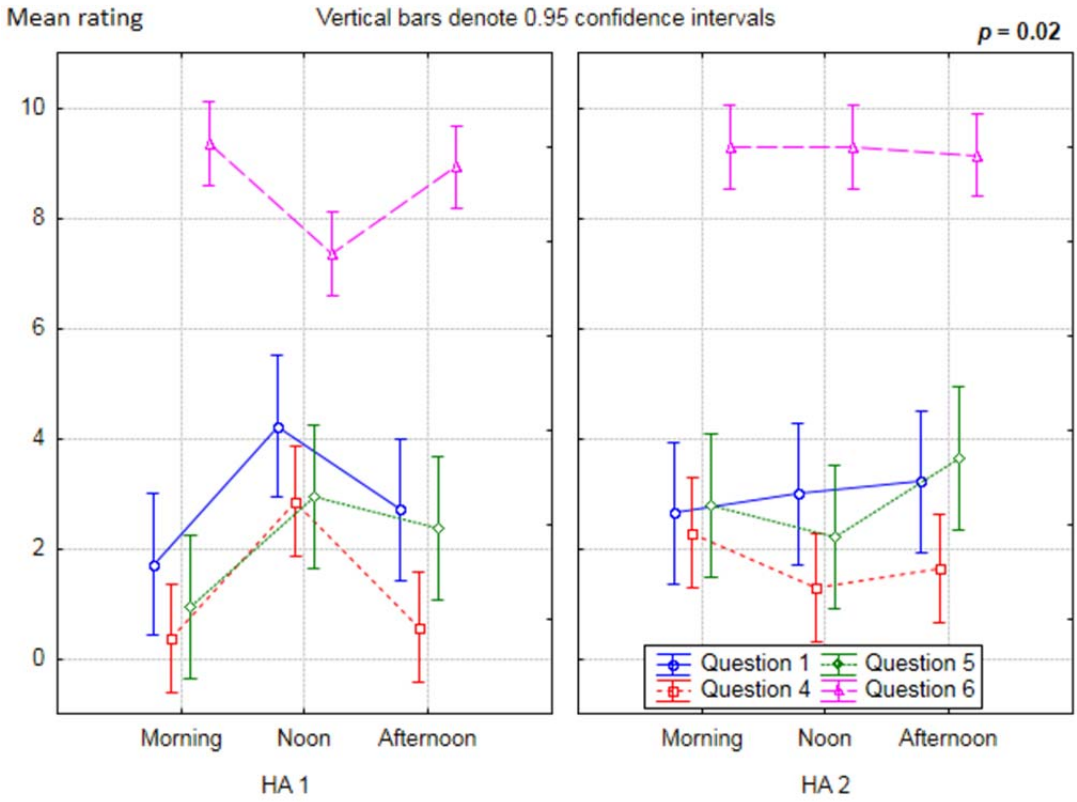

Fig. 6: Mean ratings for items on the Effort Questionnaires.

SUMMARY/CONCLUSIONS

The majority of the participants indicated that they were more 'morning' types. Yet, a clear pattern of better performance for the Saturday morning testing was not evident. In fact, results on the HINT Single Task SRTs were the poorest (largest SRTs) for Saturday morning compared to the other time of day test sessions.

Performance on the HINT for both the Single and Dual tasks showed acceptable SRTs for HA use (ranging from −1.3 to −2.7) and overall, participants demonstrated greater SRTs for the Dual Task compared to the Single Task. It may be speculated that the HA technology decreased the cognitive load allowing greater resources for processing the auditory stimuli.

As the day progressed, it was expected that the participants would demonstrate greater fatigue and less vigor. While there was a slight trend consistent with that expectation, the results were not significant. In addition, the HINT scores were actually the best (lowest SRTs) for the Saturday afternoon testing for both sets of devices. These two findings suggest that amplification may reduce the listening effort lessening the fatigue from having to work hard at listening.

The results of the Effort Questionnaire are also consistent with the findings of the POMS and HINT. Mean scores for Questions 1, 4, and 5 were all below 3 on a 11-point scale with responses closer to the *Never* or *Not At All* (0) anchor than the *All the Time* or *Completely* (10). Accordingly, participants reported minimal difficulty hearing, minimal effort in listening, and less overall physical tiredness from the day's activities while reporting that they very much enjoyed the day (mean rating for Question 6 was > 9 pts).

These results are promising showing that amplification may negate, to some degree, the negative impact of the interaction of hearing loss, fatigue, and cognitive load. Further research is clearly needed to investigate these relationships more in depth while using a larger sample size.

ACKNOWLEDGEMENTS

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