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Visual Vestibular Habituation as an Effective Treatment for Motion Sickness

Shane M. Meyer
*Pacific University*

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Abstract

Background: Motion sickness is a common problem experienced by much the population. Clinical treatments at this time are primarily pharmacological. Currently it is known that multiple exposures to motion sickness triggers can, over time, result in habituation and the patient can become free of symptoms. This repeated recurrence of sickness is not desirable or practical to daily living. Limited evidence is available for visual-vestibular habituation training that does not provoke the undesirable symptoms and can last for upwards of a year.

Method: An exhaustive search of available medical literature was conducted using Medline-OVID, CINAHL, VISIONCITE, EBMR Multifile and Web of Science using the keywords: motion sickness, visual vestibular and habituation. All articles published prior to 2000, non-English language and non-human trials were excluded by the search. Relevant articles were assessed for quality using GRADE.

Results: Three studies met inclusion criteria and were included in this systematic review. A pilot study consisting of 29 subjects demonstrated visual-vestibular habituation and reduction of motion sickness symptom scores in susceptible individuals from 13.0 ± 4.4 to 1.5 ± 3.1 eighteen weeks after habituation. A randomized controlled, double blind, trial with 20 subjects demonstrated an overall reduction in the peak velocity and in time constant of 17.2% and 22.7% respectively (p<0.05) with vestibular training. A pilot study demonstrated figure skaters, due to their habituation, were less susceptible to motion sickness than were controls (2.8 ± 2.8 vs. 16.2 ± 13.7; <0.01).

Conclusion: Since the overall GRADE of evidence is low, more research is needed before a strong recommendation for visual-vestibular habituation can be given. Current evidence, although limited, does show promising results for this non-pharmacological treatment for motion sickness.

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Master of Science in Physician Assistant Studies

First Advisor
Annjanette Sommers MS, PA-C

Second Advisor
Mary E. Von, DHEd, PA-C, DFAAPA

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Motion sickness, Visual, Vestibular

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Visual Vestibular Habituation as an Effective Treatment for Motion Sickness

Shane M. Meyer

A Clinical Graduate Project Submitted to the Faculty of the
School of Physician Assistant Studies
Pacific University
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For the Masters of Science Degree, September, 2011

Faculty Advisor: Mary E. Von, DHEd, PA-C, DFAAPA
Clinical Graduate Project Coordinator: Annjanette Sommers MS, PA-C, MS
Biography

[Information redacted for privacy]
Abstract

**Background:** Motion sickness is a common problem experienced by much the population. Clinical treatments at this time are primarily pharmacological. Currently it is known that multiple exposures to motion sickness triggers can, over time, result in habituation and the patient can become free of symptoms. This repeated recurrence of sickness is not desirable or practical to daily living. Limited evidence is available for visual-vestibular habituation training that does not provoke the undesirable symptoms and can last for upwards of a year.

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**Conclusion:** Since the overall GRADE of evidence is low, more research is needed before a strong recommendation for visual-vestibular habituation can be given. Current evidence, although limited, does show promising results for this non-pharmacological treatment for motion sickness.

**Keywords:** Motion Sickness, Visual Vestibular, Habituation
Acknowledgements

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List of Abbreviations

EVAR………………………………………………...……Earth Vertical Axis Rotation
G1.............................................................................................................................Group 1
G2.............................................................................................................................Group 2
MSS..........................................................................................Motion Susceptible Subjects
OKAN............................................................................................Opticokinetic After-Nystagmus
OKN........................................................................................................Opticokinetic Nystagmus
OVAR.........................................................................................................Off Vertical Axis Rotation
TC........................................................................................................Time Constant
VOR......................................................................................................Vestibulo-Ocular Reflex
Visual Vestibular Habituation as an Effective Treatment for Motion Sickness

BACKGROUND

Individual susceptibility to motion sickness varies greatly. However, motion sickness is more common among women, and incidence ranges from < 1% on airplanes to nearly 100% on ships in rough seas and upon becoming weightless during space travel.\(^1\) Motion sickness is often accompanied by symptoms of nausea, dizziness, fatigue and diaphoresis. These symptoms can range from mild to moderate. Prolonged motion sickness can cause vomiting, which often does not relieve the symptoms. Although not all are affected, motion susceptible individuals can often become sick when traveling by any form of transportation. The ramifications of this ailment can range from being an inconvenience to recreational boaters, to having major economical impacts on commuters traveling to and from a place of employment.

Investigations that have examined the symptoms, predictors, and causes of motion sickness and the underlying mechanisms involved in motion sickness have revealed that a conflict of visual and vestibular information, as it relates to postural control and visual stabilization, is a critical factor.\(^2\)-\(^9\) Because of the fact that subjects lacking peripheral vestibular function are immune to the stimuli that cause motion sickness as experienced by normal subjects, we know that the vestibular system plays a crucial role in the inducement of motion sickness.\(^10\) Vestibular habituation seems to be accompanied by reduced motion sickness. Thus, after a month of regular navigation, candidates for future maritime service become less sensitive to seasickness and show vestibulo-ocular reflex (VOR) habituation.\(^11\) Repetitive vestibular stimulation can therefore cause changes in VOR and at the same time a reduction in sensitivity to motion sickness.\(^12\)
Current treatments for motion sickness remain pharmacologic and generally require drug administration an hour before the offending stimulus. These treatments include the antihistamines, diphenhydramine and meclizine, as well as the anticholinergic scopolamine. The side effects of these medications are well known and not desirable. It has been shown that prolonged or repeated exposure to the motion sickness trigger or environment, provides habituation and decreased symptoms over time. However, it is not feasible or attractive for patients to undergo these repeated exposures which are accompanied by the symptoms mentioned above.

The aim of this systematic review is to help determine if the non-pharmacologic visual-vestibular habituation can serve as an effective clinical mean for the treatment of motion sickness.

**METHOD**

An exhaustive search of the medical literature was conducted using Medline-OVID, CINAHL, VISIONCITE, EBMR Multifile and Web of Science. The following terms were used to narrow the search: “Motion Sickness”, “Visual Vestibular” and “Habituation”. Duplicate articles were removed. The search was then narrowed using the following criteria: English language and published prior to the year 2000. The bibliographies of the articles were further searched for relevant sources. The articles in this review were assessed for quality using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) developed by the GRADE Working Group.\(^{13}\)
RESULTS

Initial result of the search yielded 46 articles for review. Six articles were excluded as duplicates leaving 40 articles. After screening relevant articles, a total of 3 articles met inclusion criteria and were used in this systematic review. These articles included one randomized controlled trial and two observational studies. (See Table 1).

Dai et al

In this clinical trial,\textsuperscript{14} the authors used a new approach where opposing visual and vestibular stimuli at low velocities (5-20°/s) and a low frequency (0.017 Hz) were used for habituation against motion sickness. It was further thought that these stimuli should be non-stressful, fast, effective and long lasting. Twenty nine subjects, 11 of whom had a previous history of motion sickness were enrolled in the trial. These 11 subjects were selected based off that history and placed into a motion sickness susceptible group. This group was further split into two groups, one with nine members and the other with two. Ten of these 11 subjects were female. The remaining 18 subjects (9 female & 9 male) formed a control group and were split evenly into two normal (Nl) groups, forming a total of four groups in this trial. There was no randomization or concealment. Study personnel were aware of the status of the subjects prior to placing them into groups. Subjects were also aware of which treatment group they were in. Patients were excluded if there was a history of vestibular or auditory dysfunction, migraine headaches, anxiety disorder, claustrophobia, seizures, severe vasovagal reactions or cardiovascular or autonomic disease. Ages were similar between the groups and ranged from 25-45 years. There was a disparity in gender between the susceptible and normal groups as 10 of the 11 susceptible subjects were female.\textsuperscript{14}
Baseline motion symptom scores were collected on all subjects, based on the average score obtained from motion sickness episodes over the past 1-2 years. Motion sickness scores were collected using a simplified Pensacola scale from 0 (no symptoms) to 20 (imminent emesis or strong sense of dizziness). These scores were reported verbally by each subject every 5-10s during chair rotation.

Subjects were split into the following four groups: Normal group 1 (G1)-which tested with off-vertical axis rotation (OVAR) and habituation. Normal group 2 (G2)-tested with OVAR without habituation. Motion sickness susceptible (MSS) G1 tested OVAR and habituation. MSS G2 tested habituation only as they were determined to be incapable to tolerate the off-vertical axis rotation. The experiments were conducted using a rotating chair in a circular room where the patients were secured with a seatbelt and headband for immobilization. Black and white stripes were projected on the circular wall to elicit opticokinetic nystagmus (OKN) and opticokinetic after-nystagmus (OKAN). Eye measurements were recorded using a video-oculography camera over the right eye. Initial measurements were recorded during the baseline VOR testing to check for VOR gains and time constants (TC).

OVAR testing was completed by sitting the subject in the chair that rotated at 60°/s to the right in complete darkness. After disappearance of per-rotary nystagmus the chair continued to rotate and was tilted off the vertical axis 20°. The rotation was then stopped after the subject reported a motion sickness score of 20, or after 15 minutes had elapsed; whichever came first. OVAR testing occurred on days 1, 8, 22 and 29.

Habituation consisted of the subject being placed in the rotating chair at a velocity of up to 20°/s where black and white stripes projected on the wall were oscillating at a
frequency of 0.017Hz so that this OKN stimulus was 180° out of sync with the subject’s VOR. The habituation sessions occurred on days 15-19 for 40 min/day.\textsuperscript{14}

Results after habituation showed decreased TC of 32\% to 12.5 \pm 2s for the MSS subjects and 21\% to 12.8 \pm 3.8s for normal subjects. This brought time constants to similar values between the groups; however this reduction was not as well maintained by the normal subjects. Initially VOR gain was overall higher in the susceptible group, but no overall change was noted during the habituation period for either group. Motion sickness scores of the susceptible group were higher initially as compared to the normal group, but after the 3\textsuperscript{rd} and 4\textsuperscript{th} OVAR test, the scores were approximately the same as seen in the normal group. A more significant drop in symptom scores was seen in the susceptible group. Prior to habituation the motion sickness scores for the susceptible group were 13.0 \pm 4.4 and after habituation the scores were reduced to 1.5 \pm 3.1 eighteen weeks later. Three MSS subjects reported some loss of habituation at four and a half months out with scores of 3, 4 and 10 out of 20, however the other 8 subjects were still free of motion sickness symptoms at that time. Five of the 11 susceptible subjects returned at 10 months post testing for data collection of VOR, TC and MS scores. TC were 18s (\pm 1.9s) before habituation, 10s (\pm 1.5s) after habituation and 14s (\pm 2.5s) 10 months later. Motion sickness scores were 17 (\pm 3.1) before habituation and 5.2 (\pm 4.8) upon returning.\textsuperscript{14}

The authors concluded the habituation technique used here has a rapid onset and causes little or no side effects to motion sickness susceptible individuals. They describe a high clinical potential in using this technique for treatment of motion sickness.
Clement et al

This double blind randomized controlled trial\textsuperscript{10} reviewed the effect of the amino acid acetylleucine for the reduction of nausea during head movements while rotating and facilitating vestibular habituation. They also investigated the relationship between motion sickness and subjective vertical. Twenty healthy male volunteers with an age range from 20-40 years were enrolled in the trial. Subjects were excluded if they were found to have abnormalities in the visual, vestibular or cardiovascular systems.\textsuperscript{10}

All subjects underwent initial control tests and vestibular training. For the control testing the subjects were placed in a rotating chair in the upright position. Subjects were tested in complete darkness. An infra-red light and video camera was mounted over each subject’s right eye to record eye movements and the left eye was covered. While the chair was immobile, a lighted dot that oscillated ±40° at 0.3 Hz was placed on the wall, testing for horizontal smooth eye pursuit. Horizontal VOR was then evaluated using sinusoidal oscillation of the chair in yaw at 0.2 Hz with a peak velocity of 75.4°/s while fixating on a target that was placed in a position relative to the subjects head. VOR was further tested with the chair rotating in yaw from 0°/s to 180 °/s with an angular acceleration of 180 °/s\textsuperscript{2}. This generated per-rotary horizontal nystagmus. When the per-rotary nystagmus stopped, the chair was stopped producing a post-rotary nystagmus. The chair was then rotated in the opposite direction. The post-rotary nystagmus was used to establish baseline VOR for evaluating the long-term retention effects of VOR habituation after vestibular training. The Vestibular training composed of subjects being rotated in the chair at a velocity of 180°/s. After one minute a metronome produced a signal every 5 seconds for the next one minute. This served as a cue for the subject to make a head and trunk movement to the
side at 45º and then return back upright. After the one minute of head and trunk movements, the chair was stopped and the post-rotary nystagmus was recorded. A one minute rest was given and the process was repeated but in the opposite direction of rotation. Each direction was considered a “run” and a series of 10 runs was completed with each subject.¹⁰

After the control and vestibular training the subjects were divided evenly into a placebo group and an acetylleucine group. Subjects took their assigned capsules in the evening before the first vestibular training session, and then in the mornings and evenings for the next three weeks. Test sessions were then completed on days 1-6, 22, 35 and 65, with vestibular training sessions occurring on days 1-5.¹⁰

After the five vestibular habituation training sessions, 4 subjects from the placebo group and 5 subjects from the acetylleucine group appeared to have completely habituated to the rotational stimulus. The average number of runs tolerated by all subjects also increased during the habituation training from 3.2 ± 1.0 (SD) on day one to 6.4 ± 3.7 runs on day 5. Motion sickness symptoms scores ranged on a scale from 0 for no symptoms to 51.¹⁹ These scores varied greatly between individual subjects, but overall decreased as the number of runs completed increased. There was no statistical difference between the groups in the motion sickness scores and number of runs completed. Overall results show a tolerance to motion sickness with repeated exposures.¹⁰

During post-rotary nystagmus no statistical difference was noted between the groups with gain and TC of the horizontal VOR. This data from both groups was then pooled for analysis. There was a large reduction in the peak velocity and time constant of the horizontal VOR over the course of the vestibular habituation. At the end of the
vestibular training, the overall reduction in the peak velocity and in time constant was 17.2% and 22.7%, respectively (p<0.05), compared to initial values. At two weeks post habituation, these values still remained lower than original values.\textsuperscript{10}

Overall the acetylleucine treatment did not seem to have an effect on reduction of nausea and facilitating vestibular habituation. Subjective vertical, although listed as one of the objectives of this study, was not relevant to this systematic review and will not be commented on further.

\textbf{Tanguy et al}

This pilot study\textsuperscript{12} set out to evaluate the effect of figure skating on the functional plasticity of the vestibular system by comparing VOR characteristics and motion sickness susceptibility in figure skaters to those of control subjects. Twenty two female subjects ranging from 9-19 years of age were enrolled in the trial. Eleven were figure skaters who practiced 10 hours per week including performing counterclockwise rotations. The other group of 11 served as age and sex matched controls who engaged in some physical activity without high vestibular activation involvement. Subjects who had past or present history of otologic or neurological disorders were excluded from the study.\textsuperscript{12}

All subjects underwent the same vestibular stimulation and motion sickness evaluation. Each subject was seated and immobilized in a rotary chair with the head held firmly in place with a bite-bar. Each subject then underwent three sequences in a single experimental session. All tests were performed in complete darkness. In the first sequence the chair did a sinusoidal rotation around a vertical axis for 120s (0.025Hz, amplitude ± 60°/s). The next two sequences were identical other than the direction of the rotation. For each direction of rotation the test was divided into three stages. (1) An Earth
vertical axis rotation (EVAR) for 90s. This was considered the per-rotary stimulation. (2) An off vertical axis rotation (OVAR) immediately after the first EVAR with a tilt angle of 15° and the same rotational velocity of 60°/s for 120s. The purpose of the OVAR was to induce motion sickness symptoms. After the 120s the chair was brought back to vertical position and the rotation continued for 60s in the same direction. (3) The Second EVAR stopped the rotation of the chair in 1s. This caused a post-rotary stimulation in the opposite direction for 90s.12

After the experimental session, motion sickness symptoms were assessed using the Pensacola diagnostic index methodology. This yields a score between 0 (no symptoms) to 61 (maximum symptoms).19 Eye movements, including peak slow phase velocity and time constant (TC), were recorded using video-oculography. The mean values of TC and gain (as measured by the ratio between slow phase velocity and constant head rotation velocity) were calculated from clockwise and counterclockwise examinations. The data were then pooled since no significant differences were observed within the examinations. The data were presented as means and standard deviations.12

During the sinusoidal rotation, the VOR gain was 27% lower in the skater group (0.44 ± 0.12 vs. 0.58 ± 0.01; P<0.01). During the velocity rotation, the VOR gain was again lower (32%) in the skater group as compared to the control group (0.52 ± 0.14 vs. 0.71 ± 0.12; p<0.01). There was no reported difference in the TC between the two groups (10.8 ± 1.8s vs. 10.5 ± 2.7s; p=0.78). The motion sickness score was much lower in the skater group as compared to the control group (2.8 ± 2.8 vs. 16.2 ± 13.7; p<0.01, pvariances <0.00001).12
The authors concluded that skaters, at a young age, can exhibit vestibular habituation and reduced susceptibility to motion sickness. They do point out further trials conducted with adult subjects is warranted since the vestibular system is still maturing in the patient population used here.

**DISCUSSION and RECOMMENDATIONS**

Dai et al\(^{14}\) demonstrated a decrease in motion sickness symptoms scores and time constant after low frequency, low velocity habituation. This method allowed for no significant side effects to the patients, which is a beneficial option compared to other available habituation training. The evidence reported by Dai et al\(^{14}\) supports the conclusion that visual vestibular habituation can be an effective clinical treatment for motion sickness. However this study is not without limitations. Limitations include small sample size of 29 subjects, gender bias between groups with 10 of 11 in the motion sickness susceptible group being female, lack of randomization and concealment. There is also recall bias with participants being expected to self report on symptomology. As an observational study, this trial started off with a low GRADE quality of data. This study received a single downgrade for having a small sample size. The quality of the evidence in this study was then given a GRADE of very low, with an overall significance rating of “Not Important”.

Clement et al\(^{10}\) explored the use of acetylleucine and its effects on vestibular training, nystagmus and subjective vertical. As the trial proceeded, the authors found no significant difference between the acetylleucine group and the control group for motion sickness scores, gain and time constant. However, the overall pooled data showed significant decreases in peak velocity and time constant of the horizontal VOR, as well as
an increase in the runs tolerated indicating habituation to the training. The data here support the conclusion of habituation for a treatment of motion sickness. The main limitation in this study was the small sample size of 20 subjects. There was also a gender bias here with all subjects being male. A larger sample size along with a more even gender distribution would be helpful to strengthen the data. Furthermore, a separate breakdown of male vs. female data could also be beneficial to direct clinical treatment.

As a randomized controlled trial, this study started off with a high GRADE quality of data. Due to the small sample size, this study also received a single downgrade. The quality of the data was given a final GRADE of moderate, with an overall significance rating of “Not important.”

Tanguy et al\textsuperscript{12} researched the difference of motion sickness susceptibility between figure skaters and age and sex matched controls. The VOR gains for both the sinusoidal rotation and velocity rotation phases, as well as the motion sickness symptom scores were all lower for the skater group as compared to the controls. This exhibits that a prior exposure to visual-vestibular stimulus, such as rotations that are often performed by figure skaters, can lead to habituation to motion sickness. Again this trial supports the conclusion that visual vestibular habituation can be an effective treatment for motion sickness. This study does have limitations such as the small sample size of 22 subjects, gender bias with all subjects being female and narrow age distribution ranging from 11-19 years old. However, data from the younger patient population used here, indicates visual vestibular habituation training should not be limited to adult subjects alone. Further randomized controlled trials with larger, gender matched, patient population in this age group could lead to more supporting data for visual vestibular habituation as a
clinical treatment. This observational study started off with a low GRADE quality of evidence. Due to a small sample size, this study also received a single downgrade. The final quality of the data here was given a very low GRADE quality of data with an overall significance rating of “Not important”.

CONCLUSION

Visual-vestibular habituation has demonstrated promise as a clinical option for the treatment of motion sickness. The benefits of this treatment outweigh the risks. Of the three articles included in this systematic review, the overall combined quality of the evidence, as evaluated by GRADE, is low. At this time, a weak recommendation at most for the use of visual-vestibular habituation for the treatment of motion sickness can be given. Further randomized controlled clinical trials with larger patient populations are needed to better assess the potential of visual vestibular habituation, and give a non-pharmacologic treatment option for motion sickness.
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### Tables

**Table 1. Characteristics of Studies**

<table>
<thead>
<tr>
<th>Type of Study</th>
<th>Number of Subjects</th>
<th>Gender</th>
<th>Age range (in years)</th>
<th>Blinding</th>
<th>Randomization</th>
<th>Motion sickness symptom scores</th>
<th>Time Constant (TC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prolonged reduction of motion sickness sensitivity by visual-vestibular habituation. Daj et al</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Observational</td>
<td>29</td>
<td>19F, 10M</td>
<td>25-45</td>
<td>No Blinding</td>
<td>Not Randomized</td>
<td>13.0 +/- 4.4 before, 1.5 +/- 3.1 after habituation*</td>
<td>-0.32%, -21% *</td>
</tr>
<tr>
<td><strong>Effects of vestibular training on motion sickness, nystagmus, and subjective verticle. Clement et al.</strong></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Randomized Controlled Trial</td>
<td>20</td>
<td>0F, 20M</td>
<td>20-40</td>
<td>Double Blind</td>
<td>Randomized</td>
<td>Data pooled between groups. Overall scores decreased as number of runs increasedb</td>
<td>-22.7%</td>
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<tr>
<td><strong>Vestibulo-ocular reflex and motion sickness in figure skaters. Tanguy et al.</strong></td>
<td></td>
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<tr>
<td>Observational</td>
<td>22</td>
<td>22F, 0M</td>
<td>9-19</td>
<td>No Blinding</td>
<td>Not randomized</td>
<td>2.8 +/- 2.8 in skater group vs. 16.2 +/- 13.7 in controlsc</td>
<td>No significant difference between groups**</td>
</tr>
</tbody>
</table>

* Motion sickness symptom scale ranged from 0-20.
* -32% for susceptible subjects and -21% for normal subjects after 1st habituation session.
b Motion sickness symptom scale ranged from 0-51.
c Motion sickness symptom scale ranged from 0-61.
** (2.8 +/- 1.8s; 10.5 +/- 2.8; P=0.78)
Table 2. Summary of Findings

<table>
<thead>
<tr>
<th>Study Description</th>
<th>No of studies</th>
<th>Design</th>
<th>Risk of bias</th>
<th>Inconsistency</th>
<th>Indirectness</th>
<th>Imprecision</th>
<th>Other considerations</th>
<th>Experimental</th>
<th>Control</th>
<th>Importance</th>
<th>Quality</th>
<th>Overall Quality of Data</th>
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<tbody>
<tr>
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<td>1</td>
<td>observational studies</td>
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<td>no serious inconsistency</td>
<td>no serious indirectness</td>
<td>serious*</td>
<td>none</td>
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<tr>
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<td>no serious indirectness</td>
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<td>11</td>
<td>NOT IMPORTANT</td>
<td>⊕ΟΟΟ</td>
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</tr>
</tbody>
</table>

*Small sample size used in this trial.