1 Results' analysis and discussion

Throughout the experiment, three data sources were gathered from the participants, and this chapter will show their values, will explain the process to analyze the data and will discuss their results. Each source will have its section, making up to three sessions, and they are:

- Data collected from the simulation;
- Data collected from questionnaires;
- Data collected from physiological sensors.

From this point, the data from the blind participants will be called "Blind" sample and the data from the sighted participants will be called "Sight" sample.

The processing of each data collected is rather similar and follows these steps:

1. Separate the Blind sample and the Sight sample;
2. Check if the samples are normally distributed;
   If the data is normally distributed then it is possible to use other statistical analyses and verify the results statistically.
3. Check if the "blind" sample is statistically different then the "sight" sample;
   This is one of the goals. To verify that the workload and the situation awareness of the blind participants are different from the sighted participants
4. Calculate the average of of each participant in each method;
5. Calculate the average of the participant group in each method.

1.1 Data from the simulation

Unity3D was programmed to record the time that each user spent in each scene. It is expected that the time analysis will show the following observation:

- The scene made with the white cane would be the fastest and with the less number of impacts;
  Since the participant is already used to this method, it is safe to assume that with the others methods the participant would go slower and hit more furniture on the way.

- Comparing both scenes made with the same method, the second one would have the fastest and with less impact;
  Not only this is expected but also is the intention on having two scenes with each method.

1.1.1 Time elapsed on each scene

The data collected from the participants are shown in the Table 1.1.

TABLE 1.1 – Duration grouped by participant and guidance method (in minutes).

Participant	Visual Condition	Round	Base	Audio	Haptic Belt	Virtual Cane	Mixture
001	Sight	First	10:18	13:05	6:42	6:52	7:54
		Return	12:38	6:25	7:41	10:28	5:21
001C	Blind	First	2:11	6:00	10:41	9:02	7:42
		Return	11:21	7:41	6:06	5:36	6:10
002C	Blind	First	2:02	6:17	4:32	7:34	4:08
		Return	13:32	8:06	8:02	3:35	3:57
003	Sight	First	8:06	2:14	2:51	4:21	8:11
		Return	4:11	15:25	6:50	5:25	4:18
003C	Blind	First	2:40	11:16	8:04	5:20	5:42
		Return	6:38	4:59	4:00	8:52	5:32
004	Sight	First	2:30	5:59	4:16	1:44	6:26
		Return	6:39	4:32	5:11	5:25	6:16
004C	Blind	First	2:30	6:26	4:23	5:04	3:54
		Return	8:29	5:02	11:25	4:29	6:24
005	Sight	First	2:33	6:58	5:34	5:09	7:52
		Return	8:16	8:46	4:25	6:45	3:00

The Table 1.2 show the the average time of each group on each method and they are plotted in the Figure 1.1 and 1.2. The Figure shows that there is no pattern in the relationship between the difference in the rounds of each method with the visual condition of the users.

In the Figure 1.3 is plotted the average time of each participant and it shows that

TABLE 1.2 – Duration difference grouped by participant and visual condition

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	370.80	418.62	429.59	371.73	326.67
Sight	414.61	476.13	326.95	346.47	370.17

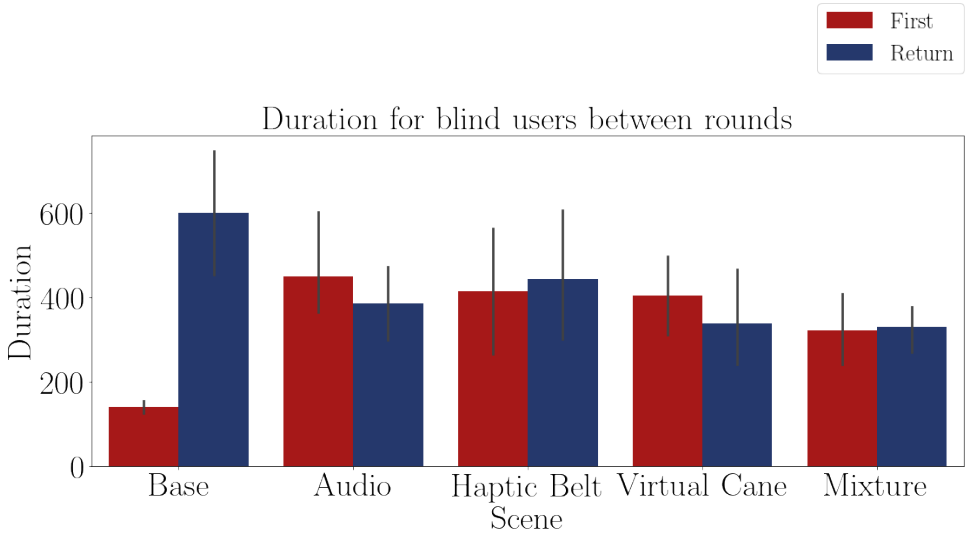

FIGURE 1.1 – Bar plot of the average time of the blind participants on each method.

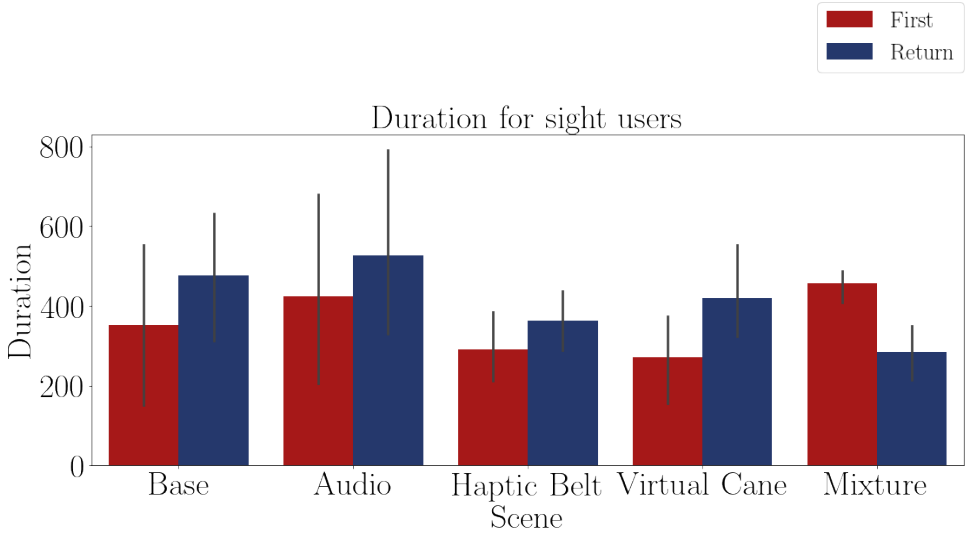

FIGURE 1.2 – Bar plot of the average time of sighted participants on each method.

there could be some difference in the time between the methods, but that would only be assured with a hypothesis test.

The Table 1.3 show the the average time grouped by visual condition and Figure 1.4 these data is plotted. The table shows a noticeable difference between the two groups. The Figure 1.4 shows that the global average of the groups in all scenes were almost the same.

TABLE 1.3 – Duration difference grouped by participant and visual Condition.

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	342.3%	-5.1%	36.1%	-8.9%	9.2%
Sight	90.5%	134.5%	38.8%	79.4%	-36.0%

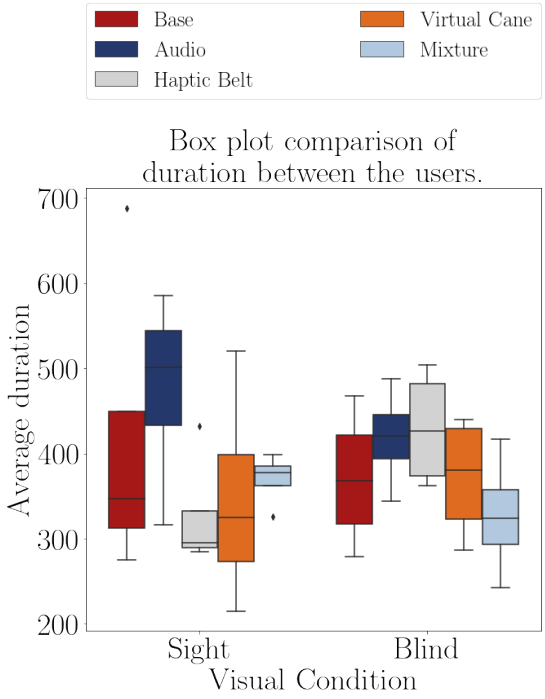

FIGURE 1.3 – Boxplot of the average time of each group on each method.

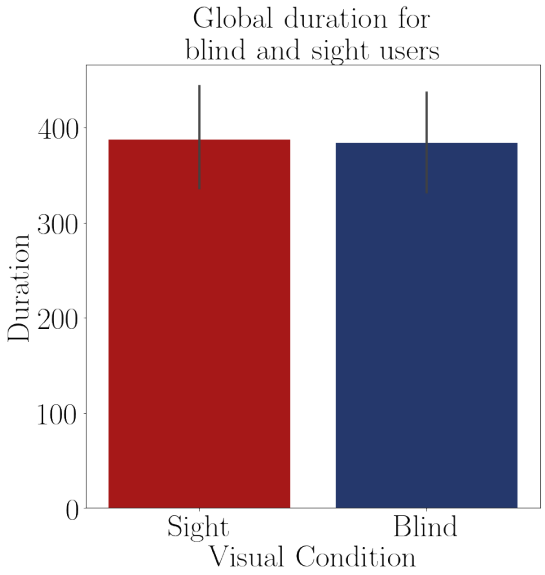

FIGURE 1.4 – Barplot of the average time of each group.

For more correct analysis, one should use statistical methods to analyze. So hypothesis tests were used, but the first step in this analysis is to check if the sample has a normal distribution.

The Table 1.4 shows the Shapiro Wilk test p-value. If this value is higher than 0.05, then the sample is normally distributed. The table 1.4 indicates that the p-values of the time averages are normally distributed hence the steps that follow are allowed to be used.

The Table 1.5 shows the T-test p-value between the time average of the blind sample and the time average of the sight sample. If this value is higher than 0.05, it means that there is no statistical differences between the samples and that both samples had the same time performance. The table 1.5 indicates the time of both the blind and the sighted users are statistically the same, with an exception of the "Audio" method.

The Table 1.6 shows the Anova test p-value of the blind time averages between the guidance methods presented in the Table **??**. If this value is higher than 0.05, there is at least one method that has no statistical difference between one from the other methods.

TABLE 1.4 – Shapiro test p-value for the duration of participant in each method.

Method	Shapiro P-Value
Audio blind	0.145
Audio sight	0.552
Haptic Belt blind	0.276
Haptic Belt sight	0.915
Virtual Cane blind	0.315
Virtual Cane sight	0.580
Mixture blind	0.377
Mixture sight	0.439

TABLE 1.5 – T test p-value for the duration for blinded users versus sighted users.

Method	T-Test P-Value
Base	0.729
Audio	0.584
Haptic Belt	0.164
Virtual Cane	0.716
Mixture	0.389

The table 1.6 indicates that at least one pair of methods have similar values.

TABLE 1.6 – Anova p-value for the duration on each method for blinded users.

Source	Squared sum	DOF	Squared average	F	P-Value ($F_0 > F$)
Between factors	62497.469	4	15624.367	1.705	0.213
Between blocks	34925.640	3	11641.880		
Experimental error	109941.961	12	9161.830		
Sampling Error	831943.973	20	41597.199		
Total	1039309.044	39			

The Table 1.7 presents a pairwise Fisher LSD test of the blind time average between all the guidance methods. If the resulted p-value is higher than 0.05 then the pair is statistically the same. The Table 1.7 shows the conclusion of each p-value, and that is that all the methods provoke a different time reaction than the time on the "Base" method, but there is no difference between them. only the "Virtual Cane" would be considered similar to the "Base" method, and looking at the Figure 1.3 above one can see that both distributions are very similar. As for the other methods, the one that improved the time spent at each scene would be the "Mixture".

Considering the on Table 1.5, the duration of the "sight" sample is similar to the "blind" sample and considering the conclusion from the ANOVA test and the Figure 1.3, the method that had the better time efficiency was the one mixing all of the methods together, and the least one was the "Audio" method.

Despite all these results above, it is noticeable some outliers in the data, especially in the first participants, when the most minor procedure errors, such as the one to stop the simulation, hence stopping the timer, had happened.

TABLE 1.7 – Cross validation p-value for the duration of each method for blinded users.

Method			Analysis
Base	X	Audio	$H_1 : \mu_{Base} \neq \mu_{Audio} **$
Base	X	Haptic Belt	$H_1 : \mu_{Base} \neq \mu_{HapticBelt} **$
Base	X	Virtual Cane	$H_0 : \mu_{Base} = \mu_{VirtualCane}$
Base	X	Mixture	$H_1 : \mu_{Base} \neq \mu_{Mixture} **$
Audio	X	Haptic Belt	$H_0 : \mu_{Audio} = \mu_{HapticBelt}$
Audio	X	Virtual Cane	$H_1 : \mu_{Audio} \neq \mu_{VirtualCane} **$
Audio	X	Mixture	$H_1 : \mu_{Audio} \neq \mu_{Mixture} **$
Haptic Belt	X	Virtual Cane	$H_1 : \mu_{HapticBelt} \neq \mu_{VirtualCane} **$
Haptic Belt	X	Mixture	$H_1 : \mu_{HapticBelt} \neq \mu_{Mixture} **$
Virtual Cane	X	Mixture	$H_1 : \mu_{VirtualCane} \neq \mu_{Mixture} **$

1.2 Data from questionnaires

There were 3 different questionnaires in this experiment. Each of these questionnaires was meant to verify one of the experiment goals:

- NASA-TLX;

  Meant to verify the mental workload of the user. Is expected that after each "First" round, the mental workload would decrease and that one of the methods would have the least mental workload. Also that there is a noticeable difference between the sight sample mental workload and the blind sample mental workload.

- Adapted SAGAT;

  Meant to verify the situation awareness and the mental map of the user. Is expected to notice an increase from the "First" round to the "Return" round at each method and a difference between the "blind" sample and the "sight" sample.

- Guidance method's questionnaire.

  Meant to assess the user experience with each method.

1.2.1 NASA-TLX

It is possible to analyze the mental workload using NASA-TLX in two different ways. The first is by analyzing only the mental demand scale and the second is by analyzing the NASA-TLX score, which is an average of the scales' rating.

1.2.1.1 Analysis of the mental demand scale

The Table 1.8 presents the mental demand averages by each participant on each scenes and they are plotted in the Figures 1.5 and 1.6.

TABLE 1.8 – Mental demand felled by the participants.

Participant	Visual Condition	Round	Base	Audio	Haptic Belt	Virtual Cane	Mixture
001	Sight	First	6	12	11	5	9
		Return	6	13	13	5	10
001C	Blind	First	3	1	14	3	6
		Return	1	1	10	2	6
002C	Blind	First	5	1	1	10	12
		Return	1	1	1	10	3
003	Sight	First	2	18	18	16	10
		Return	1	12	15	11	8
003C	Blind	First	5	5	5	8	1
		Return	3	1	1	2	1
004	Sight	First	8	17	20	12	20
		Return	5	12	15	10	15
004C	Blind	First	9	10	15	10	10
		Return	7	10	14	8	10
005	Sight	First	2	4	12	10	13
		Return	2	6	10	6	12

The Figure 1.7 has plotted the average mental demand between the rounds of each participant. The figure shows a noticeable difference between the two groups. The Figure 1.7 indicates a visual difference between the mental demand felt by the sighted participants and the mental demand felt by the blind participants. Inside the blind groups is also noticeable a difference between the methods, but the ones that are different do not show a better performance, instead of higher mental demand than the one felt during the "Base" method.

The Table 1.9 and 1.10 show the average mental demand and its variation between the rounds grouped by visual condition. The first table shows the difference between the provoked mental demand in both groupsm the second table shows how the mental demand reduced between the "First visit" and the "Return" round.

In the Figure 1.8 is plotted the average mental demand each group.

The Figure 1.9 compiles the mental demand average of the methods observed on all of the participants.

The Shapiro–Wilk normality test on the Table 1.11 shows only the "Audio" method is

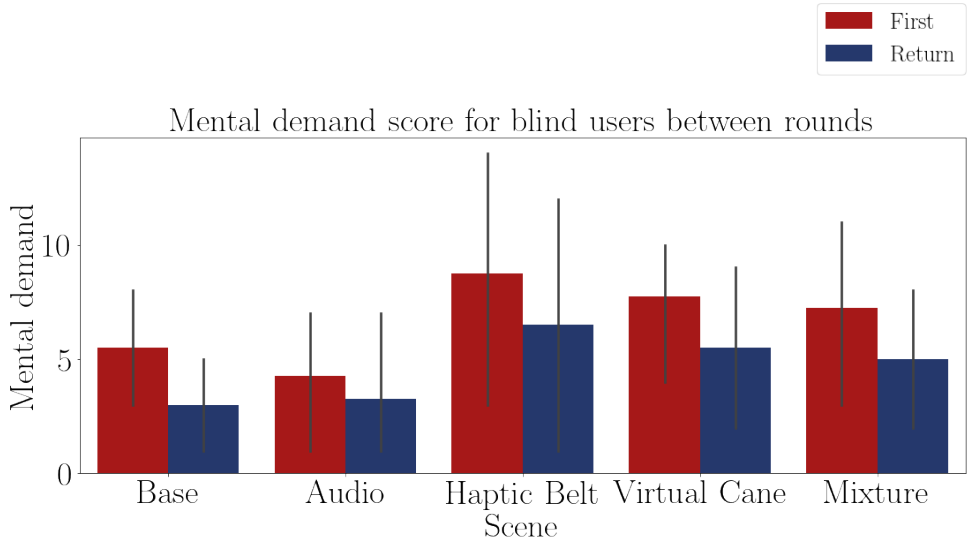

FIGURE 1.5 – Bar plot of the average mental demand of the blind participants on each method.

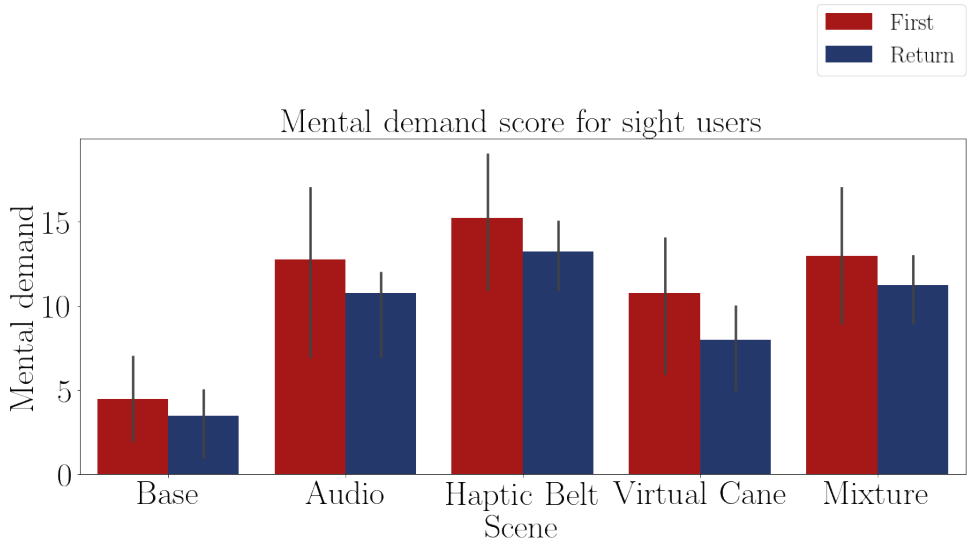

FIGURE 1.6 – Bar plot of the average mental demand of the sighted participants on each method.

TABLE 1.9 – Mental demand average grouped by participant and visual Condition

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	4.25	3.75	7.62	6.62	6.125
Sight	4.00	11.75	14.25	9.38	12.125

not normally distributed. For this method, the following analysis does not apply.

According to the T-Test presented in the Table 1.12, the methods that showed a difference in the mental demand between the "sight" sample and the "blind" sample are the "Haptic Belt" and the "Mixture" method.

The Table 1.13 shows the Anova test p-value of the mental demand of the "blind"

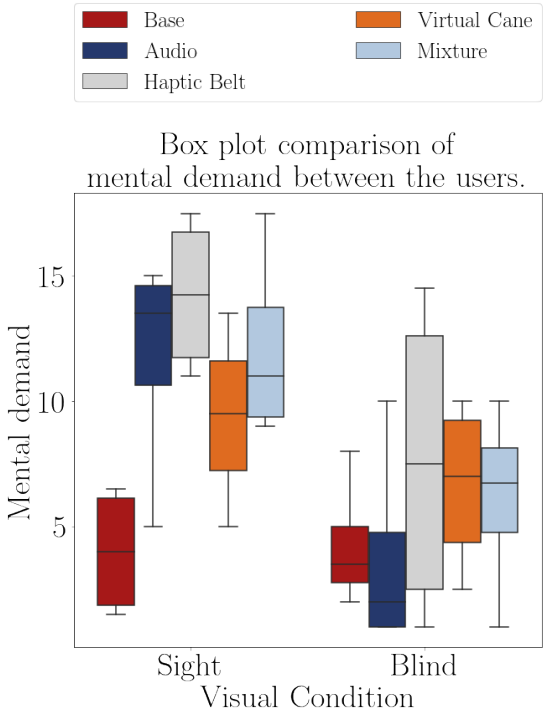

FIGURE 1.7 – Boxplot of the average mental demand of participant.

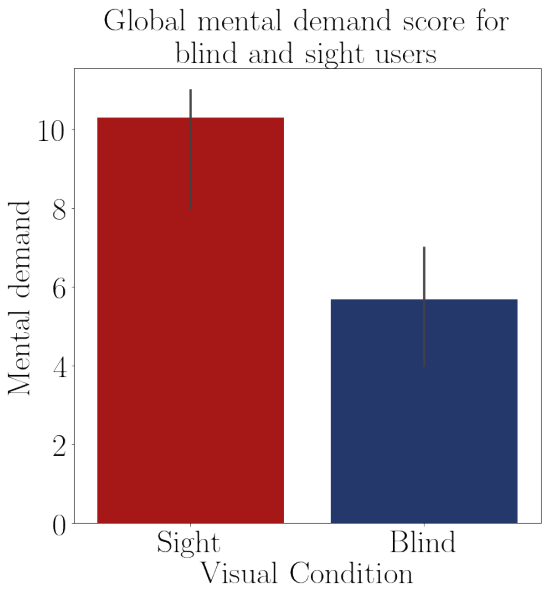

FIGURE 1.8 – Barplot of the average mental demand of each group.

TABLE 1.10 – Mental demand variation grouped by participant and visual Condition

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	-52.2%	-20.0%	-28.8%	-32.1%	-18.8%
Sight	-21.9%	-1.1%	-10.0%	-22.0%	-10.4%

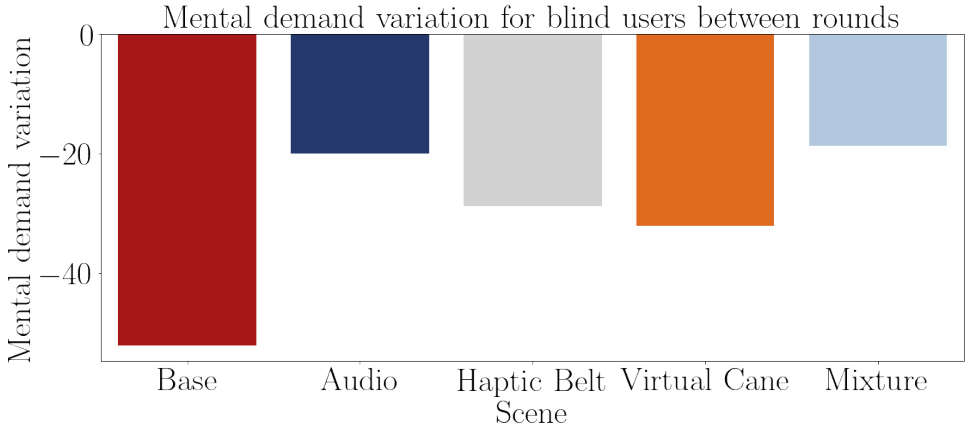

FIGURE 1.9 – Barplot of the average mental demand variation from the blind participants of each method.

TABLE 1.11 – Shapiro test p-value for the mental demand for each method and visual condition.

Method	Shapiro P-Value
Base blind	0.557
Base sight	0.198
Audio blind	0.002
Audio sight	0.357
Haptic Belt blind	0.046
Haptic Belt sight	0.704
Virtual Cane blind	0.021
Virtual Cane sight	0.385
Mixture blind	0.334
Mixture sight	0.277

TABLE 1.12 – T test p-value for the mental demand on each method for blinded users versus sighted users.

Method	T-Test P-Value
Base	1.000
Audio	0.003
Haptic Belt	0.016
Virtual Cane	0.133
Mixture	0.011

sample between the guidance methods. The p-value indicates that there is at least one method that is statistically equal to one of the other methods.

TABLE 1.13 – Anova p-value for the mental demand on each method for blinded users.

Source	Squared sum	DOF	Squared average	F	P-Value ($F_0 > F$)
Between factors	2901.806	4	725.451	1.009	0.441
Between blocks	9377.752	3	3125.917		
Experimental error	8630.194	12	719.183		
Total	20909.752	19			

The Table 1.14 presents the conclusion of a pairwise Fisher LSD test of the blind mental demand between all the guidance methods. The results show that only the "Virtual Cane" and the "Mixture" methods caused a different mental demand than the one noticed on the "Base" Method.

TABLE 1.14 – Cross validation p-value for the mental demand on each method for blinded users.

Method			Analysis
Base	X	Audio	$H_0 : \mu_{Base} = \mu_{Audio}$
Base	X	Haptic Belt	$H_0 : \mu_{Base} = \mu_{HapticBelt}$
Base	X	Virtual Cane	$H_1 : \mu_{Base} \neq \mu_{VirtualCane} **$
Base	X	Mixture	$H_1 : \mu_{Base} \neq \mu_{Mixture} **$
Audio	X	Haptic Belt	$H_0 : \mu_{Audio} = \mu_{HapticBelt}$
Audio	X	Virtual Cane	$H_1 : \mu_{Audio} \neq \mu_{VirtualCane} **$
Audio	X	Mixture	$H_1 : \mu_{Audio} \neq \mu_{Mixture} **$
Haptic Belt	X	Virtual Cane	$H_0 : \mu_{HapticBelt} = \mu_{VirtualCane}$
Haptic Belt	X	Mixture	$H_0 : \mu_{HapticBelt} = \mu_{Mixture}$
Virtual Cane	X	Mixture	$H_0 : \mu_{VirtualCane} = \mu_{Mixture}$

According to T-Test on Table 1.12, the mental demand of the "sight" sample differs from the "blind" sample in the "Haptic Belt" and in the "Mixture" method.

According to the LSD test at Table 1.14 and the Tables 1.9 and 1.10, the "Virtual Cane" and "Mixture" are statistically different from the rest. They provoked a higher mental demand than the "Base" method. Also, the "Virtual Cane" provoked the biggest variance in the mental demand, except only the "Base" method.

1.2.1.2 Analysis of the NASA-TLX score

The Table 1.15 presents the Nasa score averages by each participant on each scenes and they are plotted in the Figures 1.10 and 1.11. It is notible that after each "First" round the Nasa score diminishes for both "sight" and "blind" participants.

TABLE 1.15 – NASA score felled by the participants.

Participant	Visual Condition	Round	Base	Audio	Haptic Belt	Virtual Cane	Mixture
001	Sight	First	7.83	10.17	9.83	7.00	9.000
		Return	8.00	11.00	10.83	6.17	9.333
001C	Blind	First	4.83	4.00	8.83	5.17	6.333
		Return	4.17	4.00	6.67	4.50	6.167
002C	Blind	First	6.33	4.83	4.83	9.00	7.000
		Return	4.50	4.83	4.83	7.00	5.167
003	Sight	First	4.83	9.83	10.17	9.50	6.500
		Return	4.33	6.67	9.67	7.83	4.833
003C	Blind	First	4.00	4.00	5.33	6.67	3.500
		Return	4.00	3.83	3.67	3.50	3.500
004	Sight	First	6.67	14.83	13.67	11.50	15.833
		Return	6.83	11.83	11.83	10.83	12.167
004C	Blind	First	9.83	10.00	12.67	9.67	11.000
		Return	8.67	9.17	11.67	9.33	10.833
005	Sight	First	5.00	7.67	9.00	8.00	9.667
		Return	5.00	7.67	8.67	7.67	6.000

The Figure 1.12 shows the average Nasa score between the rounds of each participant. This figure shows a noticeable difference between the two groups, meaning that probably the Nasa score from the "sight" sample is higher than the one of the "blind" sample.

In the Figure 1.13 is plotted the average Nasa score of each group.

The Table 1.16 and the Table 1.17 show the the average and the variation of Nasa score grouped by visual condition. Both tables and show the difference between the mental

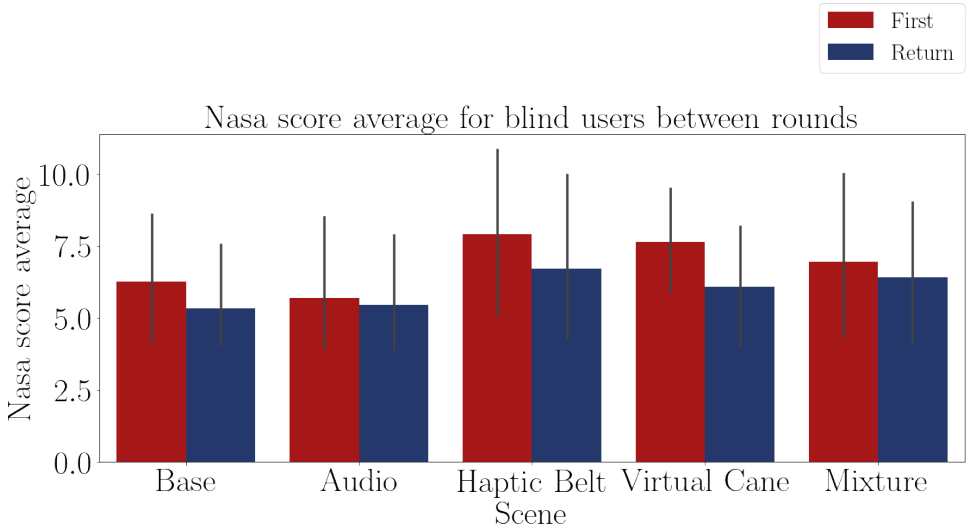

FIGURE 1.10 – Bar plot of the average Nasa-TLX score of the blind participants on each method.

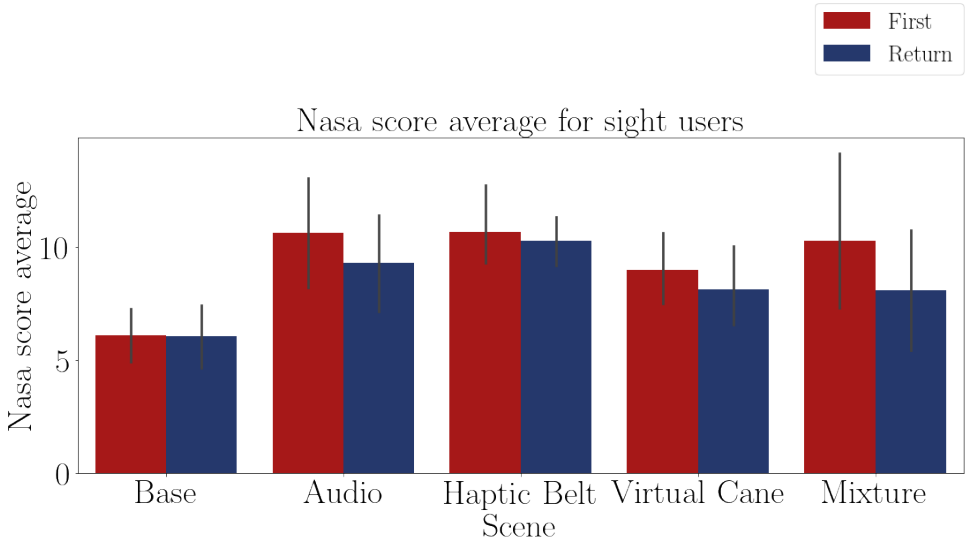

FIGURE 1.11 – Bar plot of the average Nasa-TLX score of the sighted participants on each method.

demand of the "sight" sample and the "blind" sample and how this score varies between the rounds.

TABLE 1.16 – NASA-TLX score grouped by participant and visual Condition

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	5.79	5.58	7.31	6.85	6.688
Sight	6.06	9.96	10.46	8.56	9.167

The Figure 1.14 shows the variation of the Nasa score and one can notice that the variation provoked on the "Audio" method" is a lot lesser than the other ones.

The Shapiro–Wilk normality test on the Table 1.18 shows that these data are normally

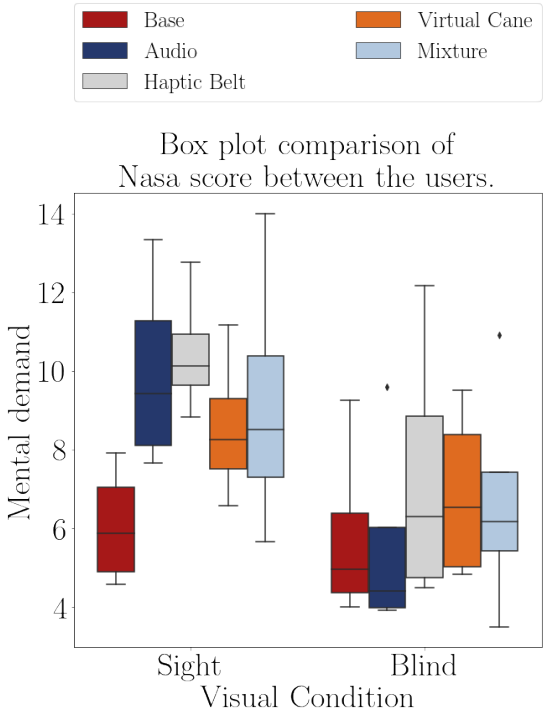

FIGURE 1.12 – Boxplot of the average Nasa-TLX score of the participants.

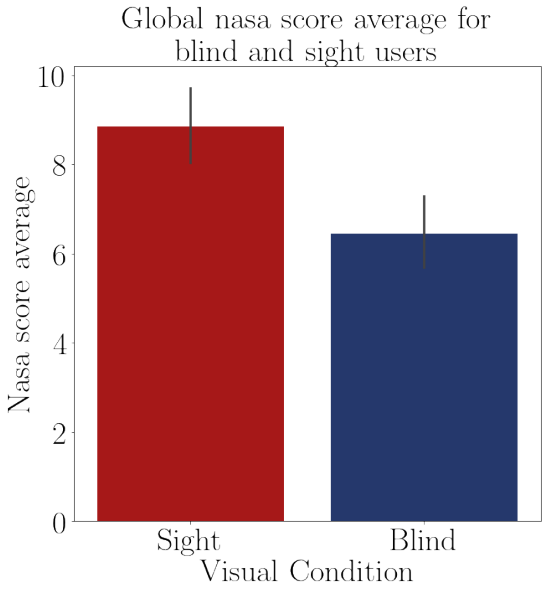

FIGURE 1.13 – Barplot of the average nasa score of each group.

TABLE 1.17 – NASA-TLX score grouped by participant and visual Condition.

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	-13.7%	-3.1%	-15.9%	-21.5%	-7.6%
Sight	-1.4%	-11.1%	-3.0%	-9.9%	-20.8%

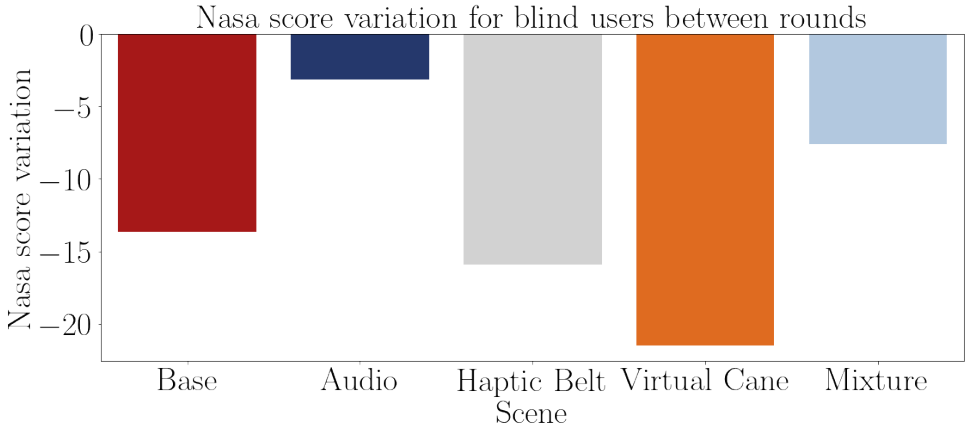

FIGURE 1.14 – Barplot of the Nasa score variation from the blind participants of each method.

distributed, with an exception of the "Audio" Nasa score. This means that further analysis cannot be applied to this method.

According to the T-Test presented in the Table 1.19 only the "Haptic belt" caused a different Nasa score between the "sight" sample and the "blind" sample.

TABLE 1.18 – Shapiro test p-value for the NASA score for each method and visual condition.

Method	Shapiro P-Value
Base blind	0.028
Base sight	0.183
Audio blind	0.002
Audio sight	0.672
Haptic Belt blind	0.188
Haptic Belt sight	0.394
Virtual Cane blind	0.455
Virtual Cane sight	0.505
Mixture blind	0.176
Mixture sight	0.609

TABLE 1.19 – T test p-value for the NASA score on each method for blinded users versus sighted users.

Method	T-Test P-Value
Base	0.781
Audio	0.004
Haptic Belt	0.033
Virtual Cane	0.129
Mixture	0.150

The Table 1.20 shows the Anova test p-value of the Nasa score, presented in the Table 1.15, of the "blind" sample between the guidance methods. The p-value indicates that there is at least one method that is statistically equal to one of the other methods so it's recommended to do a pairwise analysis between all the methods.

TABLE 1.20 – Anova p-value for the Nasa score on each method for blinded users.

Source	Squared sum	DOF	Squared average	F	P-Value ($F_0 > F$)
Between factors	17.185	4	4.296	1.690	0.217
Between blocks	211.041	3	70.347		
Experimental error	30.504	12	2.542		
Sampling Error	16.181	20	0.809		
Total	274.910	39			

The Table 1.21 presents the results of a pairwise Fisher LSD test of the blind Nasa score average between all the guidance methods. The results show that all the haptic methods and the "Mixture" are statistically different from the "Base" and "Audio" methods, but both of these groups are not different themselves.

According to T-Test on Table 1.19 only the "Haptic belt" caused a different Nasa score when comparing both groups.

According to Anova test at Table 1.20 and the 1.21 and analyzing the data in the Table 1.16 and in the Figure 1.12 the haptic methods and the "Mixture" method are provoked a

TABLE 1.21 – Cross validation p-value for the Nasa score on each method for blinded users.

Method			Analysis
Base	X	Audio	$H_0 : \mu_{Base} = \mu_{Audio}$
Base	X	Haptic Belt	$H_1 : \mu_{Base} \neq \mu_{HapticBelt} **$
Base	X	Virtual Cane	$H_1 : \mu_{Base} \neq \mu_{VirtualCane} **$
Base	X	Mixture	$H_1 : \mu_{Base} \neq \mu_{Mixture} **$
Audio	X	Haptic Belt	$H_1 : \mu_{Audio} \neq \mu_{HapticBelt} **$
Audio	X	Virtual Cane	$H_1 : \mu_{Audio} \neq \mu_{VirtualCane} **$
Audio	X	Mixture	$H_1 : \mu_{Audio} \neq \mu_{Mixture} **$
Haptic Belt	X	Virtual Cane	$H_0 : \mu_{HapticBelt} = \mu_{VirtualCane}$
Haptic Belt	X	Mixture	$H_0 : \mu_{HapticBelt} = \mu_{Mixture}$
Virtual Cane	X	Mixture	$H_0 : \mu_{VirtualCane} = \mu_{Mixture}$

higher Nasa Score in the blind participant. The Table 1.17 shows that the biggest mental demand reduction was caused by the "Virtual Cane".

1.2.2 Adapted SAGAT

In this subsection, the Sagat questionnaire is analyzed. Its result may give an idea of the mental map the participant is drawing. For each question a participant could score 1 point or a fraction of it. The total score of each participant is presented on the Table 1.22 and they are plotted in the Figures 1.15 and 1.16. It is visually noticeable that both of the groups perform better the second time they visit the room.

The Figure 1.17 shows the average Sagat score between the rounds of each participant. It is possible only to assume that some methods cause different Sagat scores than others, but both groups performed rather similarly.

The Tables 1.23 and 1.24 shows the average and the variation between the rounds of th Sagat score grouped by visual condition.

The Figure 1.18 has the above data plotted, without considering the "Base" method. Both the table and the figure also show a slight difference between the score in favor of the "blind" sample.

The Shapiro–Wilk normality test on the Table 1.25 shows that these data are normally distributed, with a p-value higher than 0.05, then it is possible to perform a T-Test to guarantee that the "blind" sample is different than the "sight" sample.

According to the T-Test presented in the Table 1.26, the only method that showed a difference in the Sagat score between the "sight" sample and the "blind" sample is the "Base" method. In the other methods both samples had a similar Sagat score.

The Table 1.27 shows the Anova test p-value of the Sagat score of the "blind" sample

TABLE 1.22 – Adapted Sagat global score by participant and guidance method.

Participant	Visual Condition	Round	Base	Audio	Haptic Belt	Virtual Cane	Mixture
001	Sight	First	1.00	0.45	0.43	0.27	0.650
		Return	1.00	0.60	0.50	0.50	0.450
001C	Blind	First	0.62	0.55	0.53	0.58	0.350
		Return	0.62	0.65	0.85	0.55	0.550
002C	Blind	First	0.68	0.45	0.40	0.45	0.625
		Return	0.53	0.50	0.40	0.65	0.850
003	Sight	First	1.00	0.68	0.60	0.40	0.675
		Return	1.00	0.60	0.72	0.62	0.750
003C	Blind	First	0.72	0.75	0.75	0.47	0.900
		Return	1.00	1.00	0.85	0.90	0.900
004	Sight	First	1.00	0.72	0.80	0.60	0.825
		Return	1.00	0.78	0.95	0.82	0.700
004C	Blind	First	0.75	0.60	0.77	0.50	0.650
		Return	0.90	0.60	0.93	0.72	0.900
005	Sight	First	1.00	0.30	0.32	0.40	0.400
		Return	1.00	0.38	0.30	0.20	0.600

TABLE 1.23 – Adapted Sagat average global score grouped by participant and visual Condition.

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	0.73	0.64	0.68	0.60	0.716
Sight	1.00	0.56	0.58	0.48	0.631

TABLE 1.24 – Adapted Sagat global score variation grouped by participant and visual Condition

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	8.9%	15.7%	23.5%	44.3%	32.9%
Sight	0.0%	13.5%	12.6%	33.1%	3.8%

between the guidance methods presented in the Table 1.22. The p-value indicates that there is at least one method that is statistically equal to one of the other methods.

The Table 1.28 presents the analysis of a pairwise Fisher LSD test of the blind average Sagat score between all the guidance methods. The results show that the "Audio" and "Virtual Cane" caused a different Sagat score than the one noticed on the "Base" Method. The rest of the methods did not significantly change it.

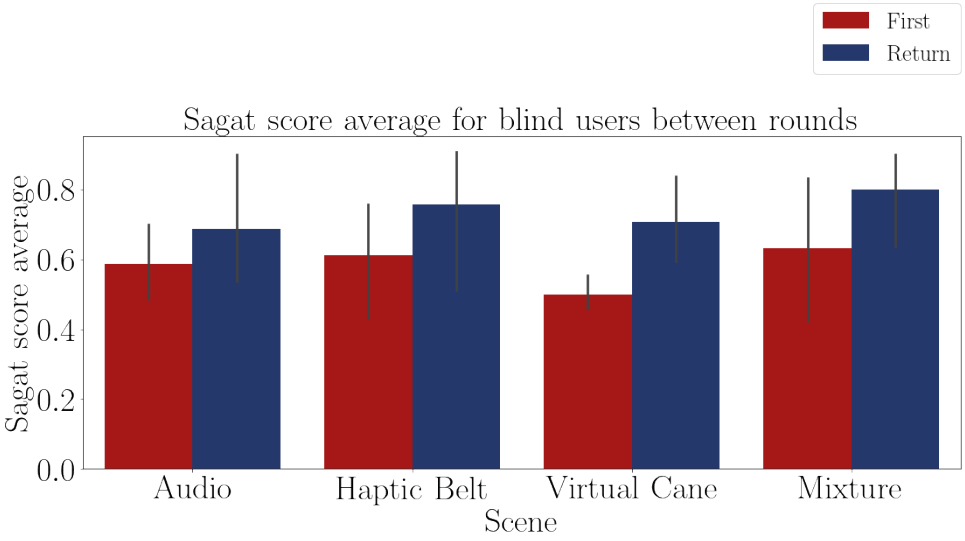

FIGURE 1.15 – Bar plot of the average Sagat score of the blind participants on each method.

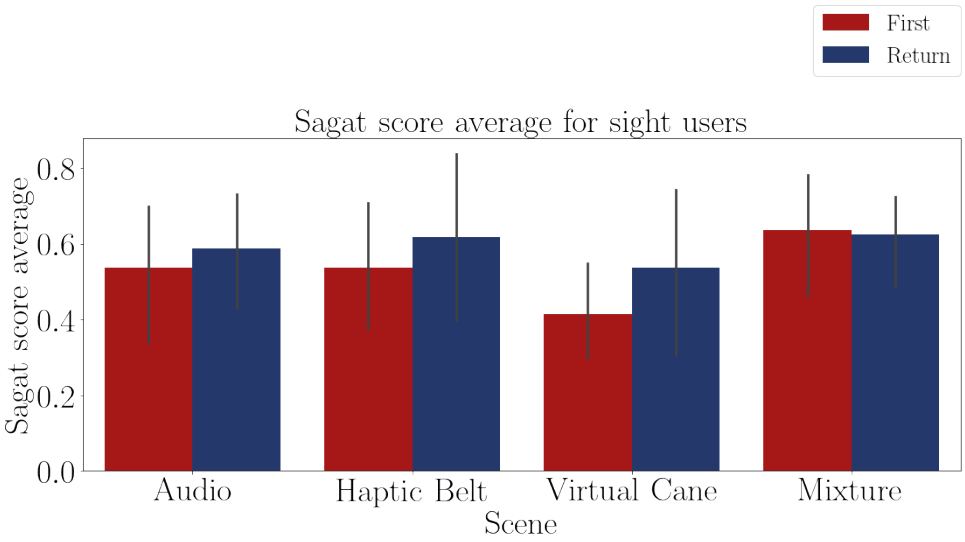

FIGURE 1.16 – Bar plot of the average Sagat score of the sighted participants on each method.

According to T-Test on Table 1.26, there is no difference in Sagat score between the "sight" and the "blind" sample except the "Base" method, which is expected.

According to both Anova test at Table 1.27 and LSD test at Table 1.28 only the "Audio" and the "Virtual Cane" provoked a similar situation awareness when compared to the "Base" method.

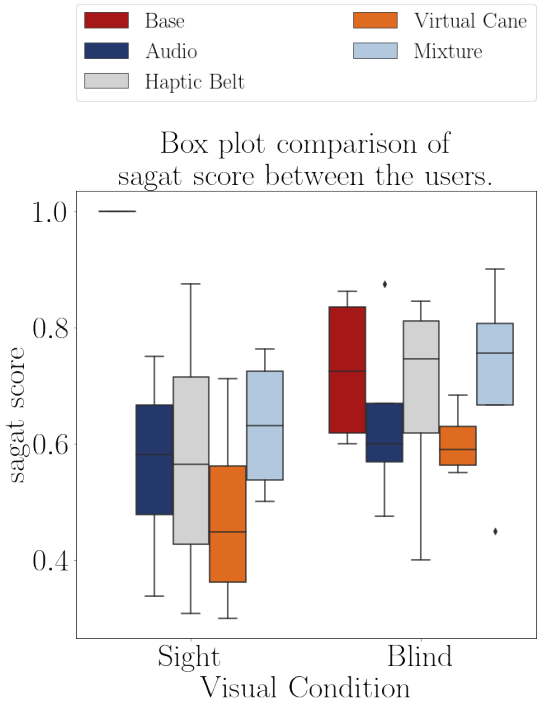

FIGURE 1.17 – Boxplot of the average Sagat score of participant.

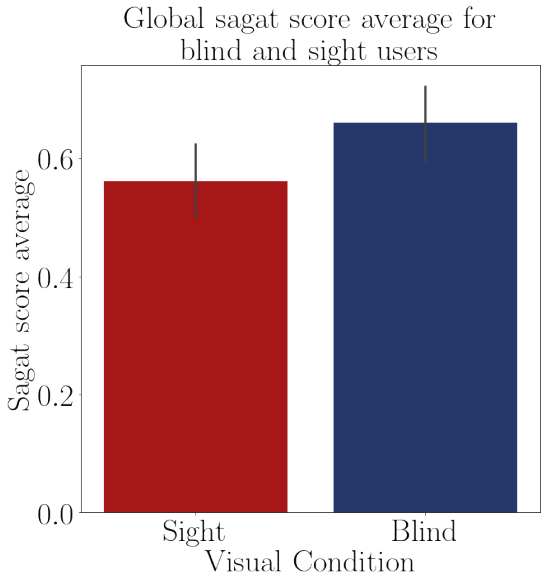

FIGURE 1.18 – Barplot of the average Sagat score of each group.

TABLE 1.25 – Shapiro test p-value for the Sagat score for each method and visual condition

Method	Shapiro P-Value
Base blind	0.619
Base sight	1.000
Audio blind	0.202
Audio sight	0.606
Haptic Belt blind	0.137
Haptic Belt sight	0.715
Virtual Cane blind	0.326
Virtual Cane sight	0.909
Mixture blind	0.124
Mixture sight	0.641

TABLE 1.26 – T test p-value for the Sagat score on each method for blinded users versus sighted users.

Method	T-Test P-Value
Base	0.000
Audio	0.397
Haptic Belt	0.355
Virtual Cane	0.182
Mixture	0.357

TABLE 1.27 – Anova p-value for the Sagat score on each method for blinded users.

Source	Squared sum	DOF	Squared average	F	P-Value ($F_0 > F$)
Between factors	0.089	4	0.022	0.966	0.461
Between blocks	0.482	3	0.161		
Experimental error	0.277	12	0.023		
Sampling Error	0.383	20	0.019		
Total	1.231	39			

TABLE 1.28 – Cross validation p-value for the Sagat score on each method for blinded users.

Method			Analysis
Base	X	Audio	$H_1 : \mu_{Base} \neq \mu_{Audio} **$
Base	X	Haptic Belt	$H_0 : \mu_{Base} = \mu_{HapticBelt}$
Base	X	Virtual Cane	$H_1 : \mu_{Base} \neq \mu_{VirtualCane} **$
Base	X	Mixture	$H_0 : \mu_{Base} = \mu_{Mixture}$
Audio	X	Haptic Belt	$H_0 : \mu_{Audio} = \mu_{HapticBelt}$
Audio	X	Virtual Cane	$H_0 : \mu_{Audio} = \mu_{VirtualCane}$
Audio	X	Mixture	$H_1 : \mu_{Audio} \neq \mu_{Mixture} **$
Haptic Belt	X	Virtual Cane	$H_1 : \mu_{HapticBelt} \neq \mu_{VirtualCane} **$
Haptic Belt	X	Mixture	$H_0 : \mu_{HapticBelt} = \mu_{Mixture}$
Virtual Cane	X	Mixture	$H_1 : \mu_{VirtualCane} \neq \mu_{Mixture} **$

1.2.3 Guidance method's questionnaire.

Finally, the Questionnaire is analyzed to give an idea about the impressions of the users with each device. This is an important evaluation to seek their impressions of each method. Each question was evaluated to favor with a higher score the methods that brought more satisfaction to the user. The Table 1.29 shows the average score of each method and they are plotted in the Figures 1.5 and 1.6

TABLE 1.29 – Guidance method questionnaire average score grouped by participant.

Participant	Audio	Haptic Belt	Virtual Cane	Mixture	Visual Condition
001	0.46	0.60	0.50	0.56	Sight
001C	0.63	0.71	0.46	0.85	Blind
002C	0.86	0.91	0.49	0.72	Blind
003	0.76	0.71	0.68	0.87	Sight
003C	0.69	0.74	0.54	0.76	Blind
004	0.86	0.77	0.57	0.64	Sight
004C	0.60	0.66	0.40	0.61	Blind
005	0.61	0.74	0.54	0.73	Sight

The Table 1.30 show the the average questionnaire score of each participant and the Figure 1.21 these data is plotted. It is possible only to assume that some methods cause different Sagat scores than others, but both groups performed rather similarly.

TABLE 1.30 – Guidance method questionnaire average score grouped by visual condition.

Visual Condition	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	0.69	0.76	0.47	0.74
Sight	0.67	0.71	0.57	0.70

The Shapiro–Wilk normality test on the Table 1.31 shows that these data are normally distributed, with a p-value higher than 0.05, then it is possible to perform the following test to check if there is a significant difference between the methods

The Table 1.32 shows the Anova test p-value of the Sagat score average of the "blind" sample between the guidance methods presented in the Table 1.29. The p-value indicates that all scores are significantly different from each other. That means that the highest scores shown in Table 1.30, which are the "Haptic Belt" and the "Mixture" methods were the most favorite by the participant.

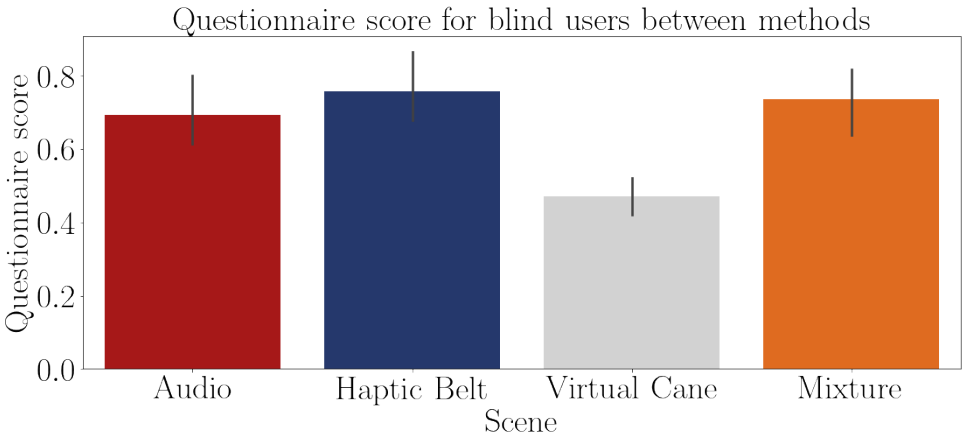

FIGURE 1.19 – Bar plot of the average mental demand of the blind participants on each method.

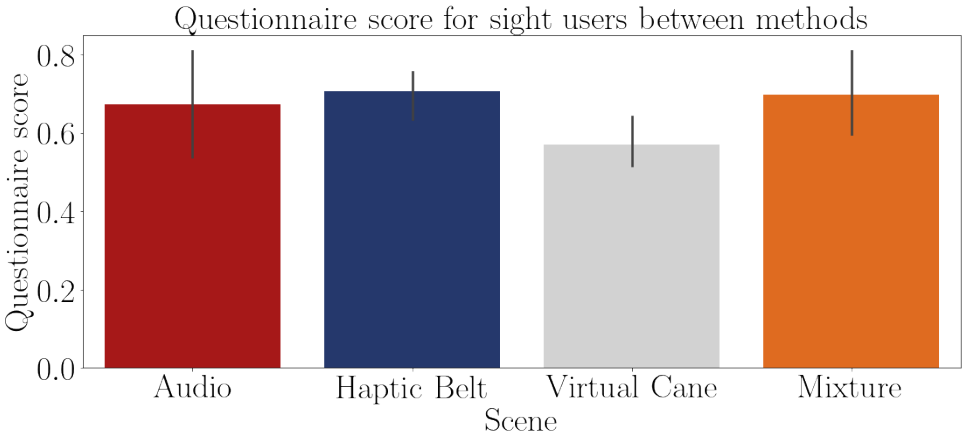

FIGURE 1.20 – Bar plot of the average mental demand of the sighted participants on each method.

TABLE 1.31 – Shapiro test p-value for the questionnaires score for each method and visual condition.

Method	Shapiro P-Value
Audio blind	0.400
Audio sight	0.882
Haptic Belt blind	0.414
Haptic Belt sight	0.369
Virtual Cane blind	0.995
Virtual Cane sight	0.577
Mixture blind	0.966
Mixture sight	0.925

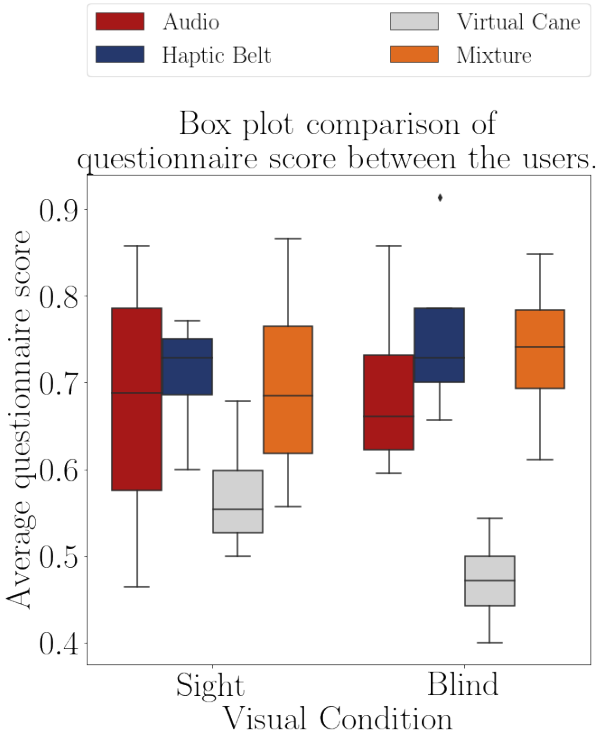

FIGURE 1.21 – Boxplot of the average questionnaire score of each group.

TABLE 1.32 – Anova p-value for the questionnaire score on each method for blinded users.

Source	Squared sum	DOF	Squared average	F	P-Value ($F_0 > F$)
Between factors	0.207	3	0.069	12.197	0.002
Between blocks	0.066	3	0.022		
Experimental error	0.051	9	0.006		
Total	0.324	15			

1.3 Data from physiological sensors

There were 3 different sensors in this experiment, 2 that collected physiological data and the one left collected temperature. The last one was used only the eliminate a possible increase in the GSR sensor caused by the increase in the temperature. These were all used to assess Mental Workload.

- Electrocardiogram (ECG) data;

  Is expected that the ECG frequency to increase at every "First" round and then a slight decrease in the next round. Also, the variation is expected to decrease in the "First" round and a slight increase in the next round.

- Galvanic skin reaction and temperature data;;

  Is expected that the GSR average to increase at every "First" round and then a slight decrease in the next round.

1.3.1 Electrocardiogram (ECG) data

The ECG analysis is divided into two different types

- Heart rate;

  This analysis checks the heartbeat frequency;

- Heart rate variance.

  This analysis checks the heartbeat frequency variance and it is done by analyzing the variation of the interval between beats.

At the beginning of each experience, a baseline data was gathered to establish a comparison between the normal state of the user and the state induced state by the scene.

After the data gathering, an algorithm in python was used to read the data and separate it accordingly to each participant, method and round. Since the participants moved during the whole experience a lot of noise was collected by the sensors, so these outliers were removed. The following steps were to normalize the data between -1 and 1 and then a peak detection method was used then, if the results were appropriate, the interval between each peak was calculated and saved to be used in the next software. This judgment was made by analyzing the plotted ECG signal and the detected peaks. If the detected peaks are not aligned with the peaks of the signal, then the method's parameters were tuned to fit the detected peaks with the signals' peaks.

The next used software was Kubios HRV Standard. Kubios is a heart rate variability (HRV) analysis software for personal non-commercial use. The Kubios HRV Standard makes it possible to use your HR monitor to examine the health of the cardiovascular system or to evaluate stress and recovery (**??**). At Kubius, the file with the saved intervals was analyzed and the results were saved in a report file to be read in python again. In python the results were plotted, tabled and statistically tested as the other data. In Appendix **??** there is a diagram with a pseudo-algorithm of this process.

This analysis was made by comparing the baseline values with the values of each round individually and between the round values themselves.

1.3.1.1 Analysis of the heartbeat frequency

The Table 1.33 presents the average heart rate by each participant on each scenes and they are plotted in the Figures 1.22 and 1.23. It is possible to see that there was no heart rate increase by any participant with the exception only of the "sight" sample in the "First" round of the "Base" method.

TABLE 1.33 – ECG average BPM felled by the participants.

Participant	Visual Condition	Round	Baseline	Base	Audio	Haptic Belt	Virtual Cane	Mixture
001	Sight	First	81.29	76.86	71.23	63.02	64.85	58.77
		Return		72.88	73.18	61.18	66.78	66.26
001C	Blind	First	78.33	75.75	60.71	71.17	59.07	68.24
		Return		71.05	58.61	66.22	64.20	70.76
002C	Blind	First	67.78	48.69	38.67	48.74	46.89	52.23
		Return		52.46	47.58	58.97	56.75	58.25
003	Sight	First	77.38	74.98	63.47	71.80	70.90	72.76
		Return		69.29	72.75	71.23	67.49	73.01
003C	Blind	First	63.45	68.37	69.89	70.95	69.41	66.94
		Return		67.34	67.44	69.68	68.82	67.37
004	Sight	First	65.32	72.97	66.85	62.45	65.94	67.86
		Return		76.85	69.48	65.65	64.58	71.86
004C	Blind	First	78.30	75.09	73.55	73.70	71.94	74.03
		Return		74.74	74.79	74.02	72.69	67.34
005	Sight	First	71.25	70.18	71.34	66.93	66.46	67.06
		Return		67.69	69.57	65.97	67.00	65.47

The Table 1.34 show the average heartbeat frequency variation between the rounds of each group and the Figure 1.24 these data is plotted. Despite all the variations being negative, which was not as expected, it possible to see that the "Audio" and the "Virtual

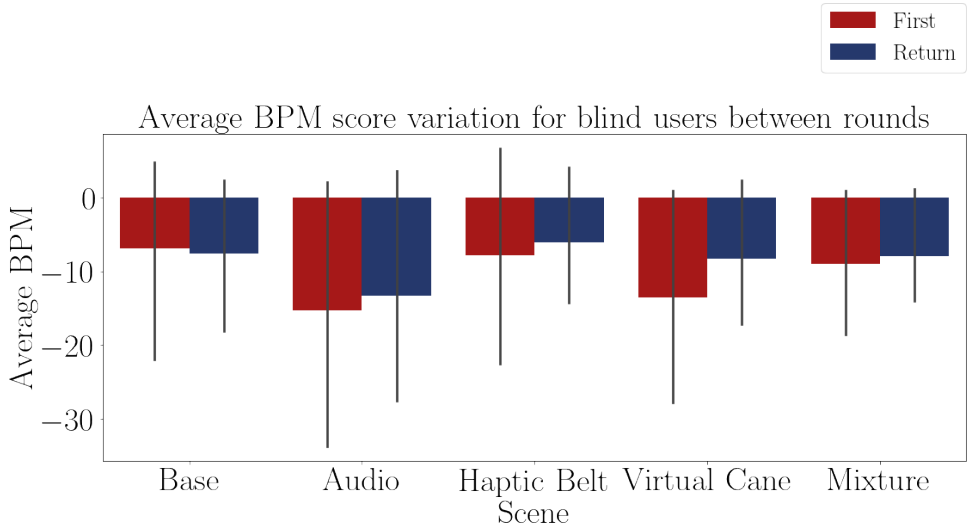

FIGURE 1.22 – Bar plot of the average heart rate of the blind participants on each method.

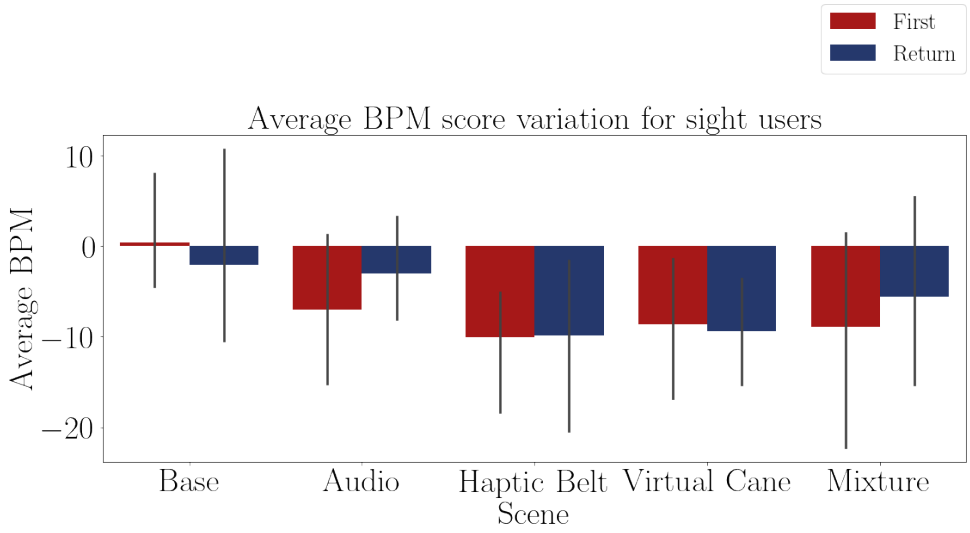

FIGURE 1.23 – Bar plot of the average heart rate of the sighted participants on each method.

cane" provoked the highest variation in heartrate.

TABLE 1.34 – ECG average BPM average in relation to the baseline grouped by participant and visual Condition.

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	-7.3%	-14.3%	-6.9%	-10.9%	-8.4%
Sight	-0.8%	-5.0%	-10.0%	-9.0%	-7.2%

The Figure 1.24 shows a comparison between both groups

The Shapiro–Wilk normality test on the Table 1.35 shows that these data are normally distributed, with a p-value higher than 0.05, then it is possible to perform a T-Test to guarantee that the "blind" sample is different than the "sight" sample.

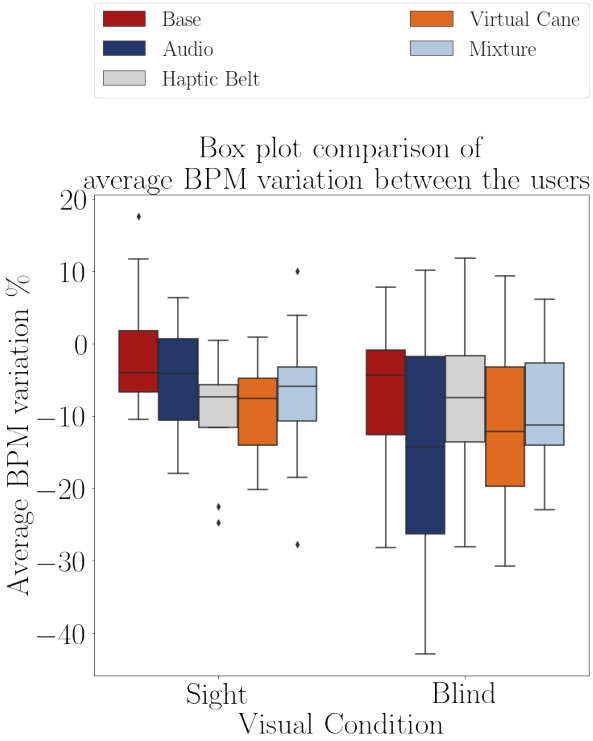

FIGURE 1.24 – Boxplot of the average heart rate of participants on each method.

According to the T-Test presented in the Table 1.36 there is no difference in the heart rate frequency variation between the sample groups.

TABLE 1.35 – Shapiro test p-value for the ecg average BPM for each method and visual condition

Method	Shapiro P-Value
Base blind	0.377
Base sight	0.086
Audio blind	0.721
Audio sight	0.969
Haptic Belt blind	0.665
Haptic Belt sight	0.059
Virtual Cane blind	0.584
Virtual Cane sight	0.743
Mixture blind	0.379
Mixture sight	0.663

TABLE 1.36 – T test p-value for the ecg average BPM each method for blinded users versus sighted users.

Method	T-Test P-Value
Base	0.279
Audio	0.215
Haptic Belt	0.594
Virtual Cane	0.750
Mixture	0.834

The Table 1.37 shows the Anova test p-value of the heart rate frequency of the "blind" sample between the guidance methods presented in the Table 1.33. The p-value indicates that there is at least one method that is statistically equal to one of the other methods.

The Table 1.38 presents the conclusion of a pairwise Fisher LSD test of the blind heart rate frequency variation between all the guidance methods. The results show that

TABLE 1.37 – Anova p-value for the BPM on each method for blinded users.

Source	Squared sum	DOF	Squared average	F	P-Value ($F_0 > F$)
Between factors	5008.288	4	1252.072	-3.770	1.000
Between blocks	6209.346	3	2069.782	-6.232	1.000
Experimental error	-3985.477	12	-332.123		
Total	7232.157	39			

the "Audio" and "Virtual cane" caused a different variation than the one noticed on the "Base" Method.

TABLE 1.38 – Cross validation p-value for the average BPM on each method for blinded users.

Method			Analysis
Base	X	Audio	$H_0 : \mu_{Base} = \mu_{Audio}$
Base	X	Haptic Belt	$H_0 : \mu_{Base} = \mu_{HapticBelt}$
Base	X	Virtual Cane	$H_0 : \mu_{Base} = \mu_{VirtualCane}$
Base	X	Mixture	$H_0 : \mu_{Base} = \mu_{Mixture}$
Audio	X	Haptic Belt	$H_0 : \mu_{Audio} = \mu_{HapticBelt}$
Audio	X	Virtual Cane	$H_0 : \mu_{Audio} = \mu_{VirtualCane}$
Audio	X	Mixture	$H_0 : \mu_{Audio} = \mu_{Mixture}$
Haptic Belt	X	Virtual Cane	$H_0 : \mu_{HapticBelt} = \mu_{VirtualCane}$
Haptic Belt	X	Mixture	$H_0 : \mu_{HapticBelt} = \mu_{Mixture}$
Virtual Cane	X	Mixture	$H_0 : \mu_{VirtualCane} = \mu_{Mixture}$

According to the Anova test at Table 1.37 and the LSD test at 1.38 the "Audio" and the "Virtual cane" method provoked a different reaction than the "Base" method and analysing the Table **??** and the Figure **??** both of them provoked the highest heartrate variation.

1.3.1.2 Analysis of the heartbeat frequency

The Table 1.39 presents the standard deviation of the interbeat interval by each participant on each scenes and they are plotted in the Figures 1.25 and 1.26. It is possible to see that there were all of the users felt an increase in the heartbeat variance.

The Figure 1.24 shows a comparison between both groups

The Table 1.40 shows the variation of the heartbeat in each round of each group. In general, all the standard deviations increased, meaning that the mental workload decreased between the "Baseline" and the method.

The Shapiro–Wilk normality test on the Table 1.41 shows that all of the "blind" sample data are normally distributed, except the "Mixture" method. In the "sight" sample only the

TABLE 1.39 – ECG Average SDNN felled by the participants.

Participant	Visual Condition	Round	Baseline	Base	Audio	Haptic Belt	Virtual Cane	Mixture
001	Sight	First	37.52	82.73	82.19	134.53	134.77	225.41
		Return		84.96	69.48	318.75	116.00	136.51
001C	Blind	First	78.55	81.29	107.06	124.74	163.97	129.05
		Return		120.72	130.88	131.59	157.59	124.79
002C	Blind	First	93.77	73.76	98.86	81.14	33.98	79.29
		Return		108.94	49.63	42.81	114.06	107.55
003	Sight	First	45.40	58.07	79.60	51.78	68.68	60.84
		Return		21.30	45.71	40.93	66.32	47.82
003C	Blind	First	26.14	36.87	38.32	35.10	42.39	43.69
		Return		52.75	41.20	44.26	42.60	46.14
004	Sight	First	91.79	120.51	121.13	154.72	128.48	125.95
		Return		139.86	100.37	122.56	140.12	119.26
004C	Blind	First	20.98	70.73	86.83	62.56	85.90	70.47
		Return		71.95	74.89	70.02	66.09	104.04
005	Sight	First	80.61	44.50	87.69	120.52	88.59	102.80
		Return		59.77	93.21	122.84	141.31	96.03

TABLE 1.40 – ECG Average SDNN average in relation to the baseline grouped by participant and visual Condition.

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	84.4%	92.1%	74.3%	102.1%	112.2%
Sight	29.3%	43.2%	152.0%	92.9%	114.7%

"Base" and the "Audio" method are normally distributed. That means that the following analyses cannot be made with those exceptions.

According to the T-Test presented in the Table 1.36 there is no difference in the heart rate frequency variation between the sample groups.

The Table 1.43 shows the Anova test p-value of the heart rate frequency of the "blind" sample between the guidance methods presented in the Table 1.39. The p-value indicates that there is at least one method that is statistically equal to one of the other methods.

The Table 1.44 presents the conclusion of a pairwise Fisher LSD test of the blind heart rate frequency variation between all the guidance methods. The results show that the "Virtual cane" and the "Mixture" method differs from the "Base" method.

According to the Anova test at Table 1.43 and the LSD test at 1.44 and the Table 1.40 the "Virtual cane" and the "Mixture" method did provoke an increase in the heartrate

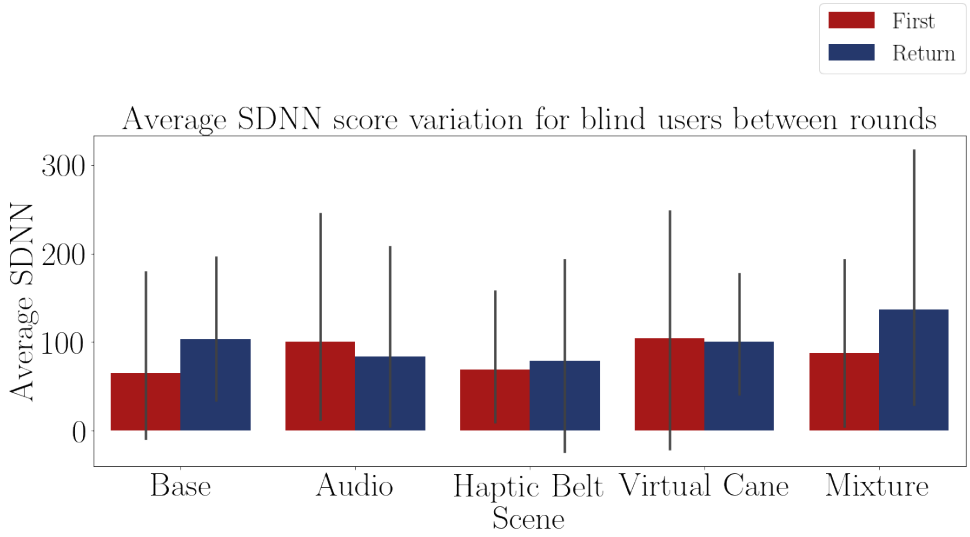

FIGURE 1.25 – Bar plot of the standard deviation of the heart of the blind participants on each method.

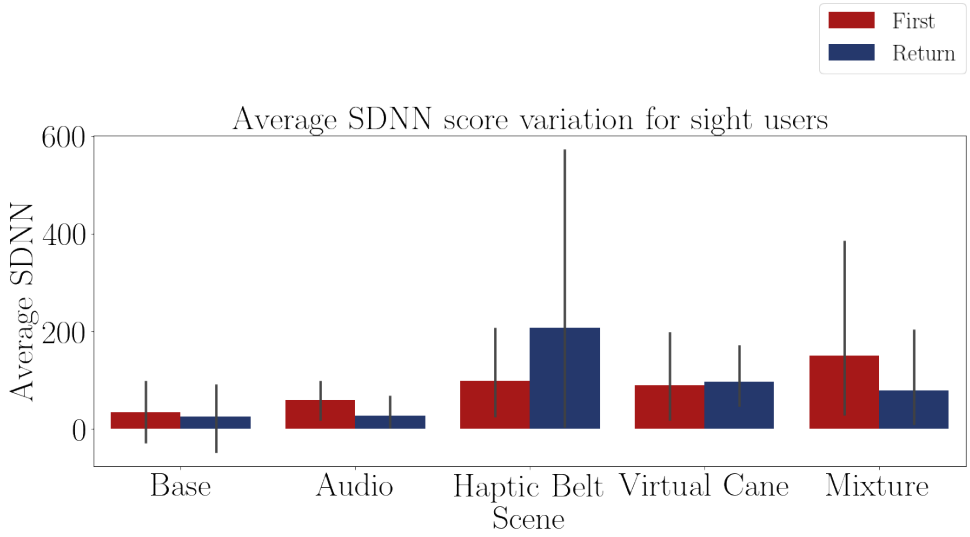

FIGURE 1.26 – Bar plot of the standard deviation of the heart of the sighted participants on each method.

variancy.

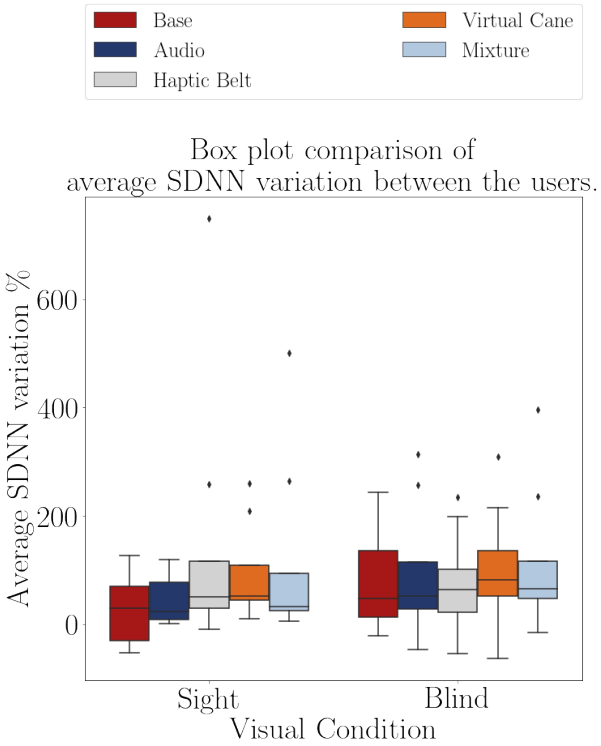

FIGURE 1.27 – Boxplot of the average heart rate of the participants on each method.

TABLE 1.41 – Shapiro test p-value for the ecg average SDNN for each method and visual condition

Method	Shapiro P-Value
Base blind	0.078
Base sight	0.347
Audio blind	0.071
Audio sight	0.130
Haptic Belt blind	0.414
Haptic Belt sight	0.001
Virtual Cane blind	0.723
Virtual Cane sight	0.015
Mixture blind	0.027
Mixture sight	0.001

TABLE 1.42 – T test p-value for the ecg average SDNN each method for blinded users versus sighted users.

Method	T-Test P-Value
Base	0.230
Audio	0.317
Haptic Belt	0.434
Virtual Cane	0.862
Mixture	0.976

TABLE 1.43 – Anova p-value for the SDNN on each method for blinded users.

Source	Squared sum	DOF	Squared average	F	P-Value ($F_0 > F$)
Between factors	7039.359	4	1759.840	1.564	0.247
Between blocks	429771.758	3	143257.253		
Experimental error	13502.730	12	1125.227		
Sampling Error	30915.582	20	1545.779		
Total	481229.429	39			

TABLE 1.44 – Cross validation p-value for the average SDNN on each method for blinded users.

Method			Analysis
Base	X	Audio	$H_0 : \mu_{Base} = \mu_{Audio}$
Base	X	Haptic Belt	$H_0 : \mu_{Base} = \mu_{HapticBelt}$
Base	X	Virtual Cane	$H_1 : \mu_{Base} \neq \mu_{VirtualCane} **$
Base	X	Mixture	$H_1 : \mu_{Base} \neq \mu_{Mixture} **$
Audio	X	Haptic Belt	$H_1 : \mu_{Audio} \neq \mu_{HapticBelt} **$
Audio	X	Virtual Cane	$H_0 : \mu_{Audio} = \mu_{VirtualCane}$
Audio	X	Mixture	$H_1 : \mu_{Audio} \neq \mu_{Mixture} **$
Haptic Belt	X	Virtual Cane	$H_1 : \mu_{HapticBelt} \neq \mu_{VirtualCane} **$
Haptic Belt	X	Mixture	$H_1 : \mu_{HapticBelt} \neq \mu_{Mixture} **$
Virtual Cane	X	Mixture	$H_0 : \mu_{VirtualCane} = \mu_{Mixture}$

1.3.2 Galvanic skin reaction and temperature data;

The GSR analysis is made by analyzing the average in each round and comparing it with the "Baseline" average. The temperature was analyzed with the GSR to see if there is some influence and by a graphical analysis there was none.

The Table 1.45 presents the average skin conductance by each participant on each scenes and they are plotted in the Figures 1.28 and 1.29. It is possible to see that in all of the methods there was an increase in the average skin conductance, meaning that the user was aroused and maybe an increase in the mental workload.

TABLE 1.45 – GSR Average felled by the participants.

Participant	Visual Condition	Round	Baseline	Base	Audio	Haptic Belt	Virtual Cane	Mixture
001	Sight	First	4.27	8.80	15.19	15.67	15.19	14.15
		Return		11.48	14.95	15.09	15.72	21.52
001C	Blind	First	0.37	0.48	1.03	3.14	3.79	3.90
		Return		0.83	1.58	2.81	4.04	4.57
002C	Blind	First	0.17	0.91	0.23	0.17	0.17	0.17
		Return		0.43	0.17	0.16	0.17	0.17
003	Sight	First	0.19	0.19	0.17	0.17	0.17	0.17
		Return		0.17	0.17	0.17	0.17	0.17
003C	Blind	First	0.30	0.56	0.56	0.62	0.85	1.09
		Return		0.62	0.63	0.65	0.92	1.06
004	Sight	First	2.60	9.71	11.18	12.60	12.92	10.34
		Return		10.89	11.97	12.25	13.47	10.16
004C	Blind	First	1.24	2.34	3.07	3.49	2.28	2.23
		Return		2.57	2.95	3.20	2.21	2.24
005	Sight	First	0.47	1.88	1.58	1.44	1.37	1.33
		Return		1.66	1.53	1.47	1.49	1.33

The Figure 1.24 shows a comparison between both groups

The Table 1.46 shows the variation of the heartbeat in each round of each grou´p. It is also possible to notice the same increase noticed before.

TABLE 1.46 – GSR average variation in relation to the baseline grouped by participant and visual Condition.

Visual Condition	Base	Audio	Haptic Belt	Virtual Cane	Mixture
Blind	72.2%	3.4%	-4.1%	2.9%	4.2%
Sight	89.9%	0.5%	-1.3%	5.9%	18.3%

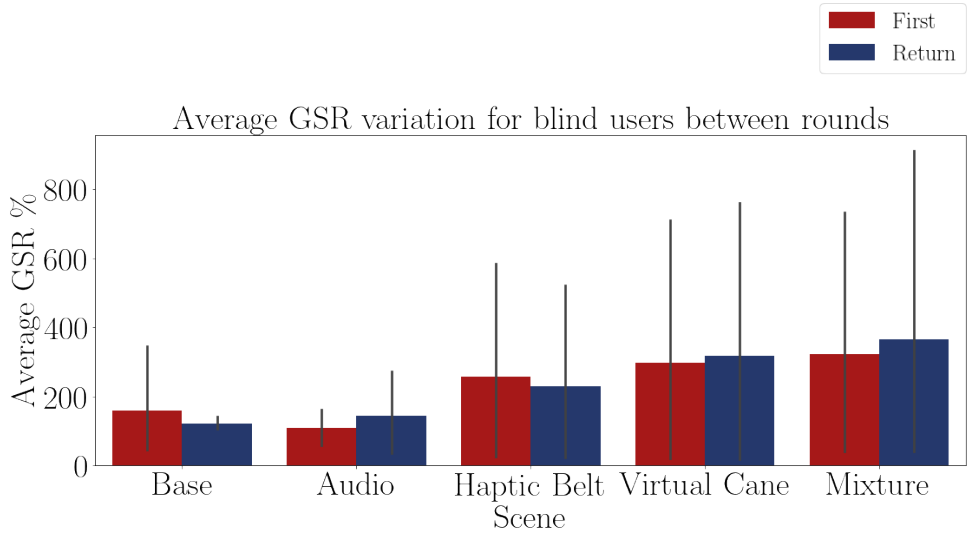

FIGURE 1.28 – Bar plot of the average skin conductance of the blind participants on each method.

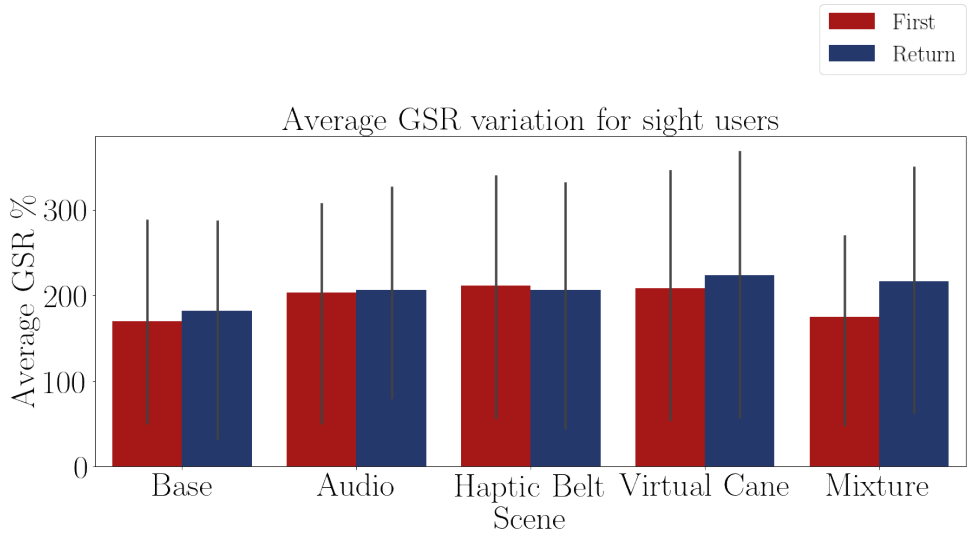

FIGURE 1.29 – Bar plot of the average skin conductance of the sighted participants on each method.

The Shapiro–Wilk normality test on the Table 1.47 shows that only the "Audio" method is normally distributed for the "blind" sample while for the "sight" sample only the "Virtual Cane" is not normally distributed

According to the T-Test presented in the Table 1.48 there is no difference in the skin conductace frequency variation between the sample groups.

The Table 1.49 shows the Anova test p-value of the skin conductance frequency of the "blind" sample between the guidance methods presented in the Table 1.45. The p-value indicates that there is at least one method that is statistically equal to one of the other methods.

The Table 1.50 presents the conclusion of a pairwise Fisher LSD test of the blind skin conductance frequency variation between all the guidance methods. The results show that the "Virtual Cane" and the "Mixture" have different variations, but since they are

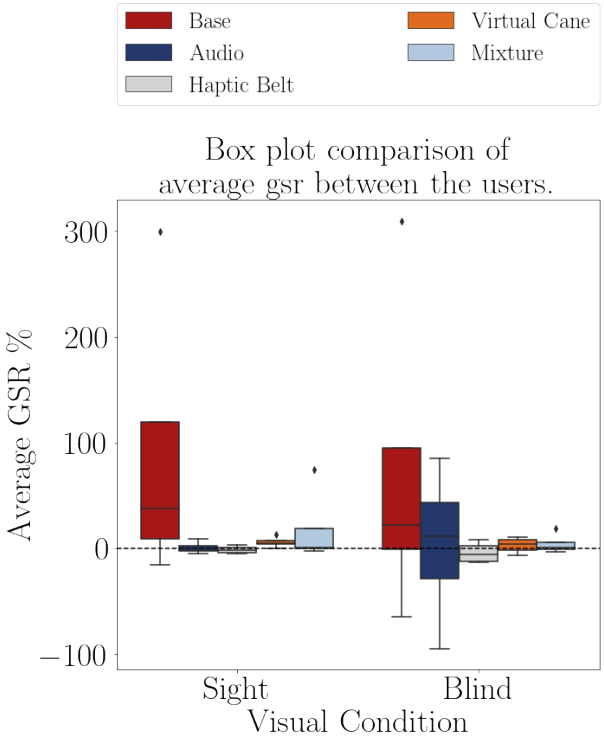

FIGURE 1.30 – Boxplot of the average skin conductace of the participants on each method.

TABLE 1.47 – Shapiro test p-value for the gsr average for each method and visual condition

Method	Shapiro P-Value
Base blind	1.000
Base sight	1.000
Audio blind	1.000
Audio sight	1.000
Haptic Belt blind	1.000
Haptic Belt sight	1.000
Virtual Cane blind	1.000
Virtual Cane sight	1.000
Mixture blind	1.000
Mixture sight	1.000

TABLE 1.48 – T test p-value for the average GSR on each method for blinded users versus sighted users.

Method	T-Test P-Value
Base	0.876
Audio	0.942
Haptic Belt	0.627
Virtual Cane	0.557
Mixture	0.493

TABLE 1.49 – Anova p-value for the GSR score on each method for blinded users.

Source	Squared sum	DOF	Squared average	F	P-Value ($F_0 > F$)
Between factors	16147.334	4	4036.833	0.762	0.569
Between blocks	34673.016	3	11557.672	2.183	0.143
Experimental error	63542.130	12	5295.177		
Total	114362.480	19			

not normally distributed this conclusion can not statistically be made.

TABLE 1.50 – Cross validation p-value for the GSR on each method for blinded users.

Method			Analysis
Base	X	Audio	$H_1 : \mu_{Base} \neq \mu_{Audio} * *$
Base	X	Haptic Belt	$H_1 : \mu_{Base} \neq \mu_{HapticBelt} * *$
Base	X	Virtual Cane	$H_1 : \mu_{Base} \neq \mu_{VirtualCane} * *$
Base	X	Mixture	$H_1 : \mu_{Base} \neq \mu_{Mixture} * *$
Audio	X	Haptic Belt	$H_0 : \mu_{Audio} = \mu_{HapticBelt}$
Audio	X	Virtual Cane	$H_0 : \mu_{Audio} = \mu_{VirtualCane}$
Audio	X	Mixture	$H_0 : \mu_{Audio} = \mu_{Mixture}$
Haptic Belt	X	Virtual Cane	$H_0 : \mu_{HapticBelt} = \mu_{VirtualCane}$
Haptic Belt	X	Mixture	$H_0 : \mu_{HapticBelt} = \mu_{Mixture}$
Virtual Cane	X	Mixture	$H_0 : \mu_{VirtualCane} = \mu_{Mixture}$

According to the Anova test at Table 1.49 and the LSD test at 1.50 only the "Virtual Cane" and the "Mixture" method provoked a different reaction than the "Base" method, but since the Shapiro test at the Table 1.47 showed that they are not normally distributed, than this conclusion has no foundation.

2 Conclusion

In this final chapter, the goals will be revised along with the results collected. It will be divided into four sections, one for each goal and a final one for future works and suggestions, and each section will have four more subsections, one for each data source gathered and one for a conclusion and commentaries for that goal.

- **Is it possible to evaluate and compare concepts of assistive device from a human factors' perspective in a virtual environment? What are the main limitations of the use of a virtual reality environment?**

  Based on the gathered data, there was a variation in the mental workload and in the situation awareness during the experiment. This variation show that the users were impacted by the experiment in the virtual reality, but since no experiment outside the virtual reality was made, it is not possible to compare this data and verify that they are similar to one provided by a real scenario.

  Although there was variations inside the experiment, there was also some unexpected results. The heartbeat and the interbeat interval standard deviation did not show the same results as the NASA-TLX indicated. That could be by the fact that the parcipants walked the majority of the time, and that polluted the sensor data, leaving to unrelatable results. It could also be caused because the experiment was made using a virtual reality, and this may have "relaxed" the participants.

  As for the limitations, the participants complained about the sound. The integrate headphone of the VIVE HMD did not provide sounds with a quality good enought for they to locate. A common commentarie was "I feel like the sound origin is inside my head", which was not true. But this can be solved by placing a real sound source in the real environment and use the HMD only for geolocalizing the participant inside de virtual environment.

  Another limitation is the real time position of the furniture. More than once, after a "First round" a furniture was not well aligned with the its virtual model. That caused some frustation on the participant as well in the researchers that had to stop the experiment to fix their position. A solution for this it would be to install real time locator on each piece of furniture.

- **Do non-BVI users, when deprived from their vision, evaluate assistive devices in a similar way as BVI users?**

  - Answers based on the simulation data

    Results from the simulation data and the T-Test showed that the only time data that was different between the groups is the "Audio". Analyzing the rest of the data one can conclude that the results had no difference.

    Graphically it is possible to notice a rather similar average duration between the two groups going along with the conclusion from the T-Test, but there is the matter of the unreliability of this data mentioned before.

  - Answers based on the subjective data

    The T-Test of each questionnaire showed that there are no differences between the groups, but the graphically is noticeable a difference between the groups. These unmatched results may be because of the small sample number.

  - Answers based on the physiological data

    The Figures indicate that there are the groups may have a similar average, but the variation of them are different in most cases. All the T-Tests indicate that both groups have the same variation of workload and arouse.

  - Final conclusions and comentaries

    The T-Test results showed in general that both groups had similar results, while some graphics showed the opposite. This happened maybe because of two reasons. First because of a small sample size. Second because of a tendency of the "sight" sample. The sighted participant all were used to technology and volunteering for experiments, while the same can not be said for the BVI participants.

2.1 Future works and suggestions

For future works related to this one it could be suggested:

- Repeat the experiment in a real situation and compare it with this one to verify the first goal;
- Repeat the experiment with more devices with different proportions of haptic and audio information sources;
- Repeat the experiment with bigger sample size and a more diverse sample to verify if the results of the hypothesis test do remain the same;