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Abstract

The effects of listening to music on cycling behaviour were evaluated. Twenty-five participants completed a track on a bicycle while listening to music with two standard earbuds, with one earbud, and with two in-ear buds. Conditions with high tempo music and loud volume were also included in the experiment, as were two mobile phone conditions, one in which participants operated the phone hand held and one handsfree condition.

Cycle speed was not affected by listening to music, but was reduced in the telephone conditions. In general the response to auditory signals worsened when participants listened to music, in particular when listening with in-earbuds loud auditory stop signals were missed in 68% of the cases. However, when listening with only one standard earbud performance was not affected. In the conditions when participants listened to high volume and to high tempo music, the auditory stop signal was also heard in significantly fewer cases. Completing a task on the mobile phone, using both handheld and handsfree sets, resulted in increased response time to an auditory stop signal and also reduced overall auditory perception. Furthermore, handsfree operation only had minor advantages opposed to hand held operation, with only response time to an auditory stop signal resulting in faster performance. This is likely to be related to the fact that both hands could be used for braking.

It is concluded that listening to music worsens auditory perception, in particular if in-ear buds are used. Furthermore, both handheld and handsfree operation of mobile phones has a negative effect on perception, potentially forming a threat to cyclist traffic safety.

1. Introduction

The effects of listening to music on task performance in general are mixed. There are two main hypotheses, which predict opposite effects. These are the Mood-arousal hypothesis and the Distraction hypothesis (see e.g. Shek & Schubert, 2009). The Mood-arousal hypothesis (Smith & Curnow, 1966, Thomson et al., 2001) predicts that arousing music will increase activity. For example, customers spend less time in a supermarket if loud (Smith & Curnow, 1966) or high tempo (Hargreaves & North, 1997) music is played, and the productivity of workers increases when they are aroused (Shek & Schubert, 2009). On the other hand, the Distraction hypothesis (Furnham & Strbac, 2002) states that music draws attention away from work-related tasks and leads to worse task performance. This is particularly true for complex work (Oldham et al., 1995). The effect of the Distraction hypothesis is in accord with the common observation that drivers will reduce music volume if a more demanding task, such as merging into heavy traffic, has to be performed (see also North & Hargreaves, 1999). North & Hargreaves (1999) also expect that non-arousing, undemanding music should be liked more than arousing (demanding) music when heard while performing a complex task, as complex music will increase the competition for the limited resources available (Kahneman, 1973) to process these streams of information. The most negative effects of music are expected to occur when performing complex tasks, in particular if these tasks and music draw upon the same resources. The main difference between the Mood-arousal and Distraction hypotheses is the stress that is put on the complexity of the tasks, and the state of the operator. When in a non-optimal state while performing a relatively simple task, music can improve performance. When already loaded by a complex task, music can have the opposite effect and be distracting and deteriorate performance.

The task at hand is thus very important in relation to these two hypotheses. Car driving covers the whole range from a relatively simple to a complex task, as determined by the demands of the environment and the capabilities of the individual driver. For example, it can be expected that driving on a quiet motorway is far less demanding than navigating through an unfamiliar foreign city. Therefore, the effects of an additional task, such as listening to music, can be expected to have different effects in different conditions. For example, while generally the use of a mobile phone has a negative effect on driving performance (Caird et al., 2008), making a phone call was found to coincide with *improved* lane control when driving on a quiet motorway (Brookhuis et al., 1991). The authors interpreted this effect as being similar to the mood-arousing hypothesis due to an alerting effect that calling may have in a low stimulus environment.

Several studies have been published on the effects of listening to music while driving a motor vehicle (e.g., Bellinger et al., 2009, Brodsky, 2002, Dalton et al., 2007, Dibben & Williamson, 2007, Nelson & Nilsson, 1990 Pecher et al., 2009) but only a few studies included the effects of music on cycling behaviour (e.g., de Waard et al., 2010). It may be relevant to know what these effects are, as due to the easy availability and popularity of mp3 players, an increasing number of cyclists are listening to music while cycling. In some countries (e.g. Germany and New Zealand) it is illegal to cycle while listening to music, whereas in other countries (e.g. The Netherlands) it is not forbidden. De Waard et al. (2010) observed that 7.7 % of the cyclists in the Dutch city of Groningen were listening to an mp3 player or iPod while Goldenbeld, Houtenbos, & Ehlers (2010) reported on the basis of results of an internet survey amongst 2500 cyclists that 15% of cyclists 18-34 years of age listen to music during (almost) every ride they make. Younger cyclists (age 12-17) reported listening to music while cycling more frequently, with 40 % of the young cyclists almost always listening to music as they rode. The percentage of cyclists who sometimes listen to music were found to be 76% for the youngest age group, and 54% for the 18-34 year old cyclists. Older cyclists also sometimes reported listening to music while cycling. With 23% of the 35-50 year old group and 14% of the 50+ year old group reporting that they sometimes rode their cycle while listening to music (Goldenbeld et al., 2010). For cycling, as with driving, the task varies from simple to complex and from low to high mental demand. Crossing a busy junction is quite different from riding on a long straight cycle path along a country road (as can be found in flat countries like the Netherlands). In their experimental study De Waard et al. (2010) found no effect on cycle speed of listening to an mp3 player with only self-reported perception of risk increasing. But in this study participants could choose their own preferred music and the volume that it was played, and no measure of response time was taken, nor was any response to auditory stimuli assessed.

From sports psychology we know that high volume music appears to increase arousal (Bishop et al., 2007, 2009). In cycling this could lead to the idea that one cycles faster when listening to loud music. Loud music may also decrease reaction time to central stimuli, but at the same time increases response time to peripheral stimuli (Beh & Hirst, 1999). Also, loud music can affect auditory perception very directly in a negative way, and auditory information is particularly important for cyclists, for example so that they can hear motor vehicles approaching from behind.

Apart from volume, the tempo of music may have an effect on arousal and performance. Participants moved faster on a treadmill exercise when high tempo music was played (Edworthy & Waring, 2006), and Bishop et al. (2009) found that listening to high tempo music reduced reaction times in a choice reaction task. Tempo is also a strong determinant of the affective response to music (Bishop et al., 2009). In that, high tempo music is more frequently highly appreciated than low tempo music. For car driving, Brodsky (2002) found that during a high music tempo condition drivers not only perceived that they were travelling at a faster driving speed but also their actual driving speed was higher than in a control condition. They also found an increase in traffic violations in the high tempo condition.

A factor that has not received much attention yet but that may be very relevant in traffic, and in particular for cycling, is the way cyclists listen to music. Unlike car drivers, who can have build-in stereo systems, cyclists tend to rely on portable music players and headphones. The earbuds on headphones come in different formats, from relatively open to in-ear buds that largely close the ears off to external sound. Cyclists wearing headphones that cover the whole ear can also be spotted. In the internet survey by Goldenbeld et al. (2010), about 5% of the music-listening cyclists reported using a loudspeaker, 23% used only one earbud, 55 % uses two earbuds or over-ear headphones and the rest reported using a different options at different times. No information on the use of in-ear buds was available.

Another activity that is often combined with driving, and also with cycling, is the use of mobile phones. The effect of operating a mobile phone while cycling was the subject of a recent study by De Waard et al. (2010) in which, the more demanding the mobile phone task that had to be performed, the larger the reduction in cycle speed that was found. More importantly, visual detection of stimuli in the periphery deteriorated while operating a handheld phone. Hyman et al. (2010) also found that pedestrians who were talking on a mobile phone, more frequently missed a very remarkable peripheral stimulus, a clown on a unicycle. However, those listening to music players did not miss the clown more frequently than people who were not listening to music. Whether effects for handheld and handsfree telephone operation are different for cyclists is not known. In car driving the differences are limited (Caird et al., 2008), particularly if the task is cognitively demanding. Therefore, when operating a handsfree phone while cycling a reduction in peripheral detection performance is expected (Amado & Ulupınar, 2005), as well as an increase in reaction time (Bellinger et al., 2009). It is possible that vehicle control is less affected when cyclists operate a handsfree telephone, as they can steer with two hands on the handlebar, however this effect has not been found in car drivers. In terms of legislation, in the Netherlands both handheld and handsfree telephoning while cycling are allowed, whereas in Germany hand held telephoning while cycling is not allowed but operating a handsfree phone is. The legislation in Germany is therefore similar as for car drivers in that country. However, as for car drivers differences between handheld and handsfree telephoning are limited, the question is whether these effects, or better the lack of these effects, are similar for cyclists. This is considered to be important as in an observation study in the Netherlands it was found that almost 3 % of cyclists manually operate their mobile phone while cycling.

In the present study, the effects of listening to music and of using a mobile phone while cycling on an isolated cycle path were studied. The type of earbud, the number of earbuds used, and the tempo and volume of music were varied. As an active control a hand-held telephone condition was included, and a handsfree condition was added. It is expected that listening to music overall will not have any effect on performance, i.e. no change in speed, peripheral detection, or response time is expected. However, high music tempo and volume are expected to increase cycle speed and reduce auditory perception. High tempo music is expected to reduce reaction time, while high volume music is expected to negatively affect peripheral visual detection. Both handheld and handsfree telephoning are expected to reduce cycle speed, and to deteriorate detection of stimuli in the periphery. No specific effects of type of earbud are expected.

2. Method

2.1 Participants

Participants were recruited via advertisements and the word of mouth. They were asked to participate with their own bicycle. Taking part in the experiment took around 45-60 minutes. Before the experiment started all participants provided informed consent and after participation they received € 10 as compensation. Eleven men and fourteen women completed the experiment and their ages ranged from 16 to 26 years.

2.2 Location and conditions

The experiment was carried out on a quiet, somewhat remote, public cycle path (the same location as used in De Waard et al., 2010). This is due to the fact that the use of such an isolated cycle path was demanded by the ethical committee for approval of the study. Participants only started a ride if no other cyclists were present and the cycle path itself was 220 m long and 1.92 m wide. Participants started at the beginning of the cycle path, and turned right at the end and continued for about 30 metres on a normal asphalt road. On this final segment of the track a stop-task was carried out.

The following conditions were included in the experiment:

C2	- Control condition, just cycling with two hands on the handlebar
C1	- Control condition, just cycling with one hand on the handlebar
M2N	- Music Normal, 120 bpm (beats/minute), 74 dB, two standard earbuds
M1	- Music, One Ear, 120 bpm, 74 dB, one standard earbud
M2IE	- Music In Ear, 120 bpm, 74 dB, two in-earbuds
M2T	- Music, Tempo, 180 bpm, 74 dB, two standard earbuds
M2V	- Music, Volume, 120 bpm, 89 dB, two standard earbuds
HH	- Telephone task, handheld
HF	- Telephone task, handsfree (one bluetooth earpiece)

A within-subjects design was used, and all participants completed all conditions once. A condition consisted of riding the cycle path from start to end and turning right at the end. The order of the conditions was balanced across participants according to a Williams design.

2.2.1 Number of earbuds

In the condition where one earbud was used, participants listened to music through a standard earbud worn in the left ear. Reason the left ear was chosen is that Leichner (1998) has shown that music entering the right hemisphere equals the effect of music entering both hemispheres.

2.2.2 Tempo

According to Brodsky (2002) music with a tempo of 85 to 110 beats/minute (bpm) results in music with a moderate tempo, and above 120 bpm, some say above 132 bpm is a fast tempo. Karageorghis, Jones, and Stuart (2008) categorised 115-120 bpm as moderate, but define above 140 bpm as fast tempo, while Edworthy & Waring (2006) only categorise music with a tempo above 200 as fast. In this study we have chosen 120 bpm as moderate, and 180 bpm as fast, above the criterion of Brodsky (2002) and Karageorghis et al. (2008), but slightly below the criterion of Edworthy & Waring (2006).

For both the 120 bpm and 180 bpm conditions participants could choose a track they liked most from three options and then the same track selected for each tempo was played for them in all relevant conditions.

2.2.3 Volume

As a normal volume 74 dB was selected. During the loud volume condition care was taken that participants would not run the risk on hearing damage, and 85 dB was selected. At 85 dB the present recommendation is not to listen longer than one hour to this level (e.g. soundadvice, 2010). In the experiment participants did not listen to this level for longer than 5 minutes, so this would not cause any damage to the participant's health. The volume level was checked with a decibel meter (Tenma TZ 360 ®).

2.2.4 Earbuds

A simple Mp3 music player (Difrnce MP850) was used, with the provided standard earbuds. These earbuds are placed outside of the ear canal without fully enveloping it. However, in the *in-ear condition* these earbuds were replaced by Sony MDR ex 35 LP in-earbuds. These in-earbuds are inserted into the ear channel and a silicone rubber sheath isolates the ear from outside sounds. In figure 1 both types of earbuds are displayed.

2.2.5 Mobile phone

A handheld telephone condition was included as active control for the experiment, as in a previous study effects of telephoning on speed and mental effort were found (see De Waard et al., 2010). A handsfree telephone condition was also added and in this condition cyclists could keep both hands on the handlebar.

In both mobile phone tasks participants were given a Sony Ericsson K320i, and in the handsfree condition they wore a single earpiece (AFV1) that communicated with the phone via Bluetooth (see figure 1). Participants were called and answered the phone either by pressing the appropriate button on the phone or on the headset. The task in both conditions was the same, counting back in steps of 7 starting from 841 or 846.

>>> Figure 1 about here

In Table 1 the comparisons of interest are displayed.

>> TABLE 1 about here

2.3 Equipment and stimuli

A GPS device (Garmin Forerunner 405) was attached to the bicycle's handlebar. From the GPS co-ordinates, cycling speed was derived. A pannier was attached to the participant's bicycle rear rack. In this pannier there was an iPod with loudspeakers that emitted the sound of a bicycle bell. During each ride this sound was played between one and four times at 80 dB.

At the end of each ride one of the test leaders honked a horn (100 dB measured from 5 metres distance), operation of the horn was not visible to the participant. Participants were instructed to stop and put one foot on the ground as quickly as possible when they heard the horn. Stopping time was measured with a stopwatch.

During each condition, task leaders unobtrusively placed two or three objects on the ground at changing locations along the cycle path. The objects were printed traffic signs or traffic lights. After each ride the participants were asked whether they had noted anything. The number of objects mentioned and the number of objects correctly identified were written down. The latter requirement meaning that the correct content of the sign or the colour of the traffic light was identified rather than just 'a sign / traffic light printed on paper' being mentioned.

2.4 Measures

2.4.1 Performance

Four performance measures were assessed: speed, reaction time, auditory perception, and visual perception.
- The average speed in km/h on the straight segment was calculated from GPS data. Also, after the bend before the auditory stop signal was given speed was assessed, also using the GPS data.
- Reaction and brake time were measured from the moment the horn sounded until the participant came to a complete standstill with one foot on the ground.
- Auditory perception (of the sound of the bicycle bell) was assessed as the number of the bells heard, and
- Visual (peripheral) perception was the number of signs reported, and the number correctly named.

2.4.2 Self-reports

After each condition a mental workload rating on the RSME, Rating Scale Mental Effort (Zijlstra, 1993) was taken. The RSME is a unidimensional scale which ranges from 0 to 150. A rating of 12 denotes "almost no effort", 58 is marked as "rather much effort", and 112 as "extreme effort". An estimate of experienced risk was also assessed; on the same scale where the word "risk" was substituted for "effort" (the same scale had been used in the previous study, see De Waard et al., 2010). A subjective impression of cycling speed (in km/h) was also recorded, and in the music conditions participants were asked how they experienced the volume of the music they just listened in relation to the volume they normally (would) listen to music while cycling. After all conditions were completed general information about cycling experience and habits concerning telephoning and listening to music while cycling were collected.

2.5 Procedure

Upon arrival participants filled out the informed consent. After providing general information about the procedure, the GPS watch and a pannier containing loudspeakers and an iPod for the auditory stimuli were attached to the participant's bicycle. No particular instructions with regard to cycle speed were given, only to cycle as they would normally do. As indicated earlier, participants used their own bicycle with which they were familiar.

2.6 Analyses

Statistical analyses were performed with SPSS 16.0 for Windows. Repeated measures GLM (General Linear Model) were applied to the continuous variables. Post hoc contrasts to compare conditions within GLM of paired t-tests were applied with adapted alpha to compensate for chance capitalisation. Ordinal variables were evaluated with a Friedman test. If statistically significant, pair wise comparisons for these parameters were performed with a Wilcoxon signed rank test.

3. Results

3.1 Participants

Average age of the participants was 22 years (SD 2.65). All used their mobile phone while cycling; 54% reported doing so several times a week and 17% did so less than once a month. A relatively large proportion, 36%, indicated never to listen to music while cycling, 24% indicated that they listen to music for a maximum of four times per month, and 30% reported that they do so a few times a week to almost always. The majority of them usually listened to music while cycling with two earbuds, two listened with one earbud, and one used loudspeakers.

Due to technical problems (battery of the Bluetooth headset, stopwatch timing error) a few cells did not contain data for some of the participants.

3.2 Performance measures

3.2.1 Speed

No differences in cycle speed between the control and music conditions were found ($F(5,85)<1$, NS, Figure 2). However, the use of a mobile phone, was accompanied by a reduction in speed ($F(1,20)=57.14$, $p<0.001$, $\eta_p^2=0.74$). Both handheld and handsfree phone use had this effect, with no difference between these two telephone conditions ($F(1,21)<1$, NS).

>> FIGURE 2 about here

3.2.2 Reaction and brake time

Response time to the stop signal could of course only be assessed provided the stop signal was heard. In the control and telephone conditions, and in the M1 (one earbud) condition all stop signals were heard. However the stop signal was not heard in 4% of the M2N trials (two earbuds), in 16 % of the MT (high tempo) trials, in 24% of the MV (Volume) trials, and in 68% of the M2IE (in-ear earbuds) trials (Friedmantest, $\chi^2=73.8$, df=8, $p<0.001$). Results of a Wilcoxon signed-rank test comparing the music conditions with the two hands on the handlebar control condition reveal no significant effect for M1 and M2N, however, in the conditions M2V($Z=-2.45$, $p = 0.014$), MT ($Z=-2.00$, $p = 0.046$), and M2IE ($Z=-4.12$, $p < 0.001$) the stop signal was missed significantly more often.

>> FIGURE 3 about here

In over two out of three times the stop signal in the in-ear earbud condition was missed, therefore this condition was excluded from the response time statistical analyses. In figure 3 average response time is depicted. No difference between the remaining four music conditions were found (F(3,56)<1, NS), nor was a difference between the music and control condition found (M2N vs. C2; F(1,23)<1, NS).

The effect of telephoning was evaluated by comparing the two control conditions with the two telephone conditions (see Table 1). Telephoning increased response and brake time by 0.29 seconds on average (F(1,21)=5.8, p=0.025, η_p^2=0.22). Also, approach speed was significantly *lower* for the telephone conditions (F(1,20)=11.3, *p*=0.003, η_p^2=0.36) (see Table 2).

Post-hoc tests revealed a difference in response time between handheld and handsfree conditions (F(1,23)=5.9, p = 0.023), as well as in approach speed (F(1,21)=5.49, p=0.029). The control conditions did not differ in approach speed, but response and brake time was slower in the one hand on the handlebar condition (F(1,22)=16.6, p=0.001). Between music conditions the approach speed did not differ.

>> TABLE 2 about here

3.2.3 Auditory perception

Apart from the response to the auditory stop signal, participants had to count the number of auditory stimuli heard during each condition. As the number of these stimuli, the sound of a bicycle bell, differed every ride, a new variable was created; the number of missed stimuli. A significant effect of music condition was found (χ^2=66.58, df=5, *p*<0.001). Wilcoxon signed-rank test comparing the music conditions with the two hands on the handlebar control condition revealed a negative effect on perception compared to control for all conditions but the M1 (one earbud) condition (M2N: Z=-3.87, p < 0.001, M2V: Z=-4.21, p < 0.001, M2T:Z=-4.10, p < 0.001, M2IE:Z=-4.34, p < 0.001).

Compared with other conditions the effects on auditory perception were as follows:

No. of Hands	C1-C2	Z = -0.577,	NS
Music	M2N-C2	Z = -3.327,	p = 0.001
In-ear	M2N-M2IE	Z = 1.362,	NS
No. earbuds	M2N-M1	Z = -2.579,	p=0.010
Tempo	M2N-M2T	Z = 0.585,	NS
Volume	M2N -M2V	Z = 1.156,	NS
Telephoning	HH-C1	Z = -2.638,	p=0.008
Telephoning	HF-C2	Z = -2.940,	p=0.003
Handsfree	HH-HF	Z = -0.285,	NS

In Figure 4 the percentage of participants that heard all and the percentage that heard none of the auditory stimuli is depicted. These are the extremes, as the number of stimuli per condition varied between one and four therefore displaying information on exact how many bells heard on average would distort effects. By instead using the number of missed simuli it is clear to see in which conditions participants performed well and in which ones they did not.

>> FIGURE 4 about here

3.2.4 Visual peripheral detection

Detection of stimuli in the periphery was not affected by listening to music (χ^2= 7.55, df=5, NS), nor did the number of signs that were correctly named in the music and control conditions differ (χ^2=6.99, df=5, NS). For the two telephone conditions there was also no effect found on detection performance (χ^2=4.42, df=3, NS), however, there was a negative trend in performance on naming the signs which were detected (χ^2=11.43, df=3, p=0.010). In the control conditions 53% of the participants were not able to name any of the signs correctly and in the telephone conditions this percentage increased to 66%.

3.3 Self reports

3.3.1 Self-reported effort

No effect of listening to music (M2N vs. C2) on the self-reported effort-ratings were found, however, in conditions of high tempo and high volume music, more mental effort was reported to be required to complete the ride when compared with the normal tempo and normal volume level conditions (high tempo: $F(1,24)=10.7$, $p=0.003$, high volume: $F(1,24)=8.47$, $p=0.008$). The same applies to operating the telephone compared with the control conditions ($F(1,23)=37.7$, $p<0.001$). However, the handheld and handsfree conditions did not differ significantly from each other ($F(1,23)=1.04$, NS). In Figure 5 the results are graphically presented.

>> FIGURE 5 about here

3.3.2 Self-reported risk

With regard to experienced risk, almost all contrasts of interest (Table 1) differed from each other (see Figure 6). More risk is reported in the control conditions when riding with one hand compared with two ($F(1,24)=8.79$, $p=0.007$), when listening to music ($F(1,24)=5.52$, $p=0.027$), when listening to high volume music ($F(1,24)=9.83$, $p=0.004$) compared with normal volume, and when listening with in-earbuds compared with normal earbuds ($F(1,24)=11.7$, $p=0.002$). Operating a telephone (both handfree and handheld) was also considered to be more risky ($F(1,23)=28.2$, $p<0.001$) than when riding without a telephone.

>>> FIGURE 6 about here

3.3.3 Estimated cycling speed

Participants drove slower in the telephone conditions, and experienced those rides as slower ($F(1,22)=38.9$, $p < 0.001$). They also estimated their cycle speed to be lower when cycling with one hand compared with two (15.3 vs. 16.3 km/h, $F(1,24)=8.33$, $p=0.008$), while actual measured speed between these conditions did not differ. When comparing the handsfree and handheld telephone condition, participants estimated their cycling speed in the handsfree condition to be slightly higher than in the handheld condition (13.4 km/h vs. 14.3 km/h, $F(1,22)=4.99$, $p=0.036$).

All effects are summarised in Table 3.

>> TABLE 3 about here

3.3.4 Opinion about Volume

After each condition where participants listened to music, their opinion about the volume of the music was asked. In Table 4 their experience of volume is shown compared with the level they normally listen to music when cycling, or, if they did not listen to music while cycling, the volume level they in general listen to music. Remarkable is that 44% of the participants state that the high volume condition was the same or even quieter than the volume level they normally listen to while cycling. For the in-ear phone this percentage is slightly lower, but still accounted for 38% of all participants.

>>> Table 4 about here

4. Discussion and conclusions

In the introduction it was argued that the environment in which people listen to music matters for the effect it has on performance. The ethical committee that approved the present study demanded a safe environment, i.e. no other traffic present, and this should be kept in mind when generalising results. The experimental conditions were “easy” compared with cycling through heavy urban traffic. Thus, it was expected that effects of music would be more in line with the Mood-arousal hypothesis than with the Distraction hypothesis. On the basis of the Mood arousal hypothesis one would expect a higher cycle speed, this, however, was not found in the present study. Similar effects on speed would be expected from loud and high tempo music; but again these were not found. However, the study does not provide support for the distraction hypothesis either, as cyclists did not slow down when listening to music, rather there was simply no effect of music on speed. Also only in the high tempo and high music conditions did self-reported effort increase, indicating that more processing capacity was required for the task of cycling and listening to music.

One not very surprising, though important finding for traffic safety, is that auditory perception was affected in a negative sense, with less auditory information being processed when listening to music. In particular when participants made use of in-ear plugs the effects were quite large as the stop signal was missed by two out of three participants in this condition. Increased use of in-earbuds may be a serious threat to traffic safety if worn during cycling. It is likely that a similar effect can be found for pedestrians, although it would be less critical due the fact that pedestrians are typically more physically removed from interactions with vehicles, though experimental work should confirm this. High volume and high tempo music also increased response time to the auditory signal, a potentially dangerous effect. It should be noted however that participants rated experienced risk and effort to be higher in those conditions, and this awareness might result in behaving more cautiously in traffic.

Effects of mobile phone use were partly similar to effects found in the previous study (De Waard et al, 2010), i.e., a lower cycle speed, but effects on peripheral vision were less pronounced than previously found. On the other hand, in the present study response to auditory stimuli was also assessed, and in the telephone conditions negative effects on response time were found. The finding that handsfree telephoning does not seem to be a safer alternative, in that it had similar effects as handheld telephoning on speed and auditory perception, could have important legal implications as cycling behaviour deteriorates as a result of both handheld and handsfree mobile phone use. In the handsfree condition only response time was faster, and perhaps that is due to the fact that two hand brakes could be operated. Unfortunately we did not assess type of brake; hand brake or back-pedal(ling) brake. When comparing the two mobile phone conditions, self-reported risk for handsfree telephoning was lower than for hand held telephoning, which might actually be an indication of incorrect feelings of relative safety compared with handheld telephoning.

In summary, the effects of listening to music are most pronounced on the perception of other auditory information. In particular response to auditory information is limited when listening to music using in-earbuds. However, riding with only one earbud has no negative effects on cycling behaviour and performance on the auditory tasks. As many cyclists use auditory information to determine whether other traffic is nearby or approaching, these results are quite relevant for road safety.

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Effects of listening to music, and of using a handheld and handsfree telephone on cycling behaviour

Figure and Table Captions

Table 1. Comparison of conditions, C2 (Control condition, two hands), C1 (Control condition, one hand), M2N (Music Normal), M1 (Music, One Ear), M2IE (Music In-Earbuds), M2T (Music, High Tempo), M2V (Music, High Volume), HH (Telephone task, handheld), and HF (Telephone task, handsfree).

Table 2. Approach speed before the stop-signal

Table 3. Summary of results

Table 4; Volume in the music conditions compared with level participant normally listens to (or would listen to) music while cycling. Percentage respondents that say that the volume in experiment was…

Figure 1. Earbuds used, on the left the standard earbugs, in the centre the in-earbugs. The Bluetooth earpiece used in the mobile phone handsfree condition is on the right

Figure 2. Average cycling speed in km/h. C1= Control one hand on the handlebar, C2= Control, 2 hands on handlebar, M1= music in one ear, M2N= music in two ears, M2V + music high volume (2 ears), M2T= Music, high tempo, M2IE= music two ears, in-ear phones, HH=mobile phone, handheld, HF= mobile phone, handsfree. Error bars reflect 95% confidence intervals.

Figure 3. Average reaction and brake time (seconds) to an auditory stop signal (s). C1= Control one hand on the handlebar, C2= Control, 2 hands on handlebar, M1= music in one ear, M2N= music in two ears, M2V + music high volume (2 ears), M2T= Music, high tempo, M2IE= music two ears, in-ear phones, HH=mobile phone, handheld, HF= mobile phone, handsfree. Error bars reflect 95% confidence intervals.

Figure 4. Percentage participants that heard all or none of the auditory stimuli. C1= Control one hand on the handlebar, C2= Control, 2 hands on handlebar, M1= music in one ear, M2N= music in two ears, M2V + music high volume (2 ears), M2T= Music, high tempo, M2IE= music two ears, in-ear phones, HH=mobile phone, handheld, HF= mobile phone, handsfree

Figure 5. Score on the Rating Scale Mental Effort. C1= Control one hand on the handlebar, C2= Control, 2 hands on handlebar, M1= music in one ear, M2N= music in two ears, M2V + music high volume (2 ears), M2T= Music, high tempo, M2IE= music two ears, in-ear phones, HH=mobile phone, handheld, HF= mobile phone, handsfree.

Figure 6. Subjective Risk Rating (Scale ranges from 0-150, 0 = no risk). C1= Control one hand on the handlebar, C2= Control, 2 hands on handlebar, M1= music in one ear, M2N= music in two ears, M2V + music high volume (2 ears), M2T= Music, high tempo, M2IE= music two ears, in-ear phones, HH=mobile phone, handheld, HF= mobile phone, handsfree.

Table 1.

	C1	M2N	M2IE	M1	M2T	M2V	HH	HF
C2	[1]	[2]						[7]
C1							[7]	
M2N			[3]	[4]	[5]	[6]		
M2IE								
M1								
M2T								
M2V								
HH								[8]
HF								

[1] Effect of cycling with one or two hands on the handlebar
[2] Effect of listening to music (normal earplugs)
[3] Effect of normal vs in-earbuds
[4] Effect of listening via one vs. two earbuds
[5] Effect of high tempo
[6] Effect of high volume
[7] Effect of mobile phone use
[8] handheld vs handsfree phone use

Table 2.

Condition	C1	C2	M1	M2N	M2V	M2T	M2IE	HH	HF
average (km/h)	18.0	18.6	18.6	18.9	18.5	18.4	18.2	16.6	17.3
SD	2.84	3.00	2.42	2.63	2.34	2.06	2.49	2.39	2.26

Table 3.

	1-2 hands	Music	in ear	1-2 earbuds	Tempo	Volume	Telephone	Handheld vs handsfree
Conditions compared: *Measure*	**C1-C2**	**C2-M2N**	**M2IE-M2N**	**M1-M2N**	**M2T-M2N**	**M2V-M2N**	**HH/HF-C1/C2**	**HH-HF**
Speed							phone < control	
Stop signal heard			in ear < normal earbuds		high tempo < normal tempo	high volume < normal volume		
Response Time to Stopsignal	one > two hands						phone > control	handheld > handsfree
Approach Speed							phone < control	handheld < handsfree
Visual detection							phone < control (trend)	
Auditory perception		music < control		one > two earbud			phone < control	
ReportedMental effort (RSME)					high tempo > normal tempo	high volume > normal volume	phone > control	
reported risk	one > two hands	music > control	in ear > normal			high volume > normal volume	phone > control	
estimated speed	one < two hands						phone < control	handheld < handsfree

Table 4

Music volume level in the experimental condition was…	Normal (74dB)	High Volume (89 dB)	In-Ear condition (74 dB)
Much quieter	8%	0%	4%
Quieter	24%	8%	18%
The same	36%	36%	16%
Louder	20%	16%	44%
Much louder	12%	40%	28%

Figure 1
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Figure 2

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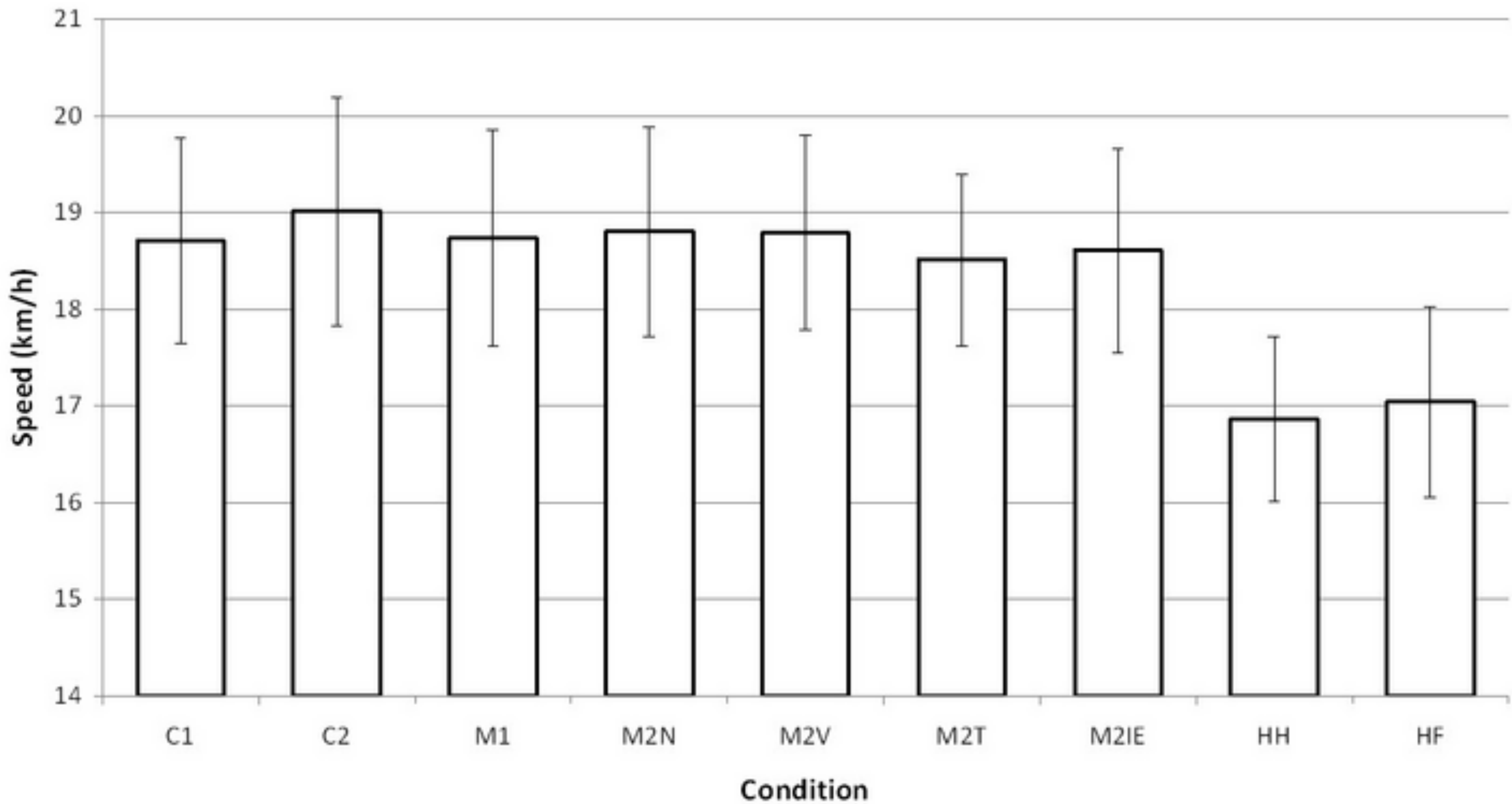

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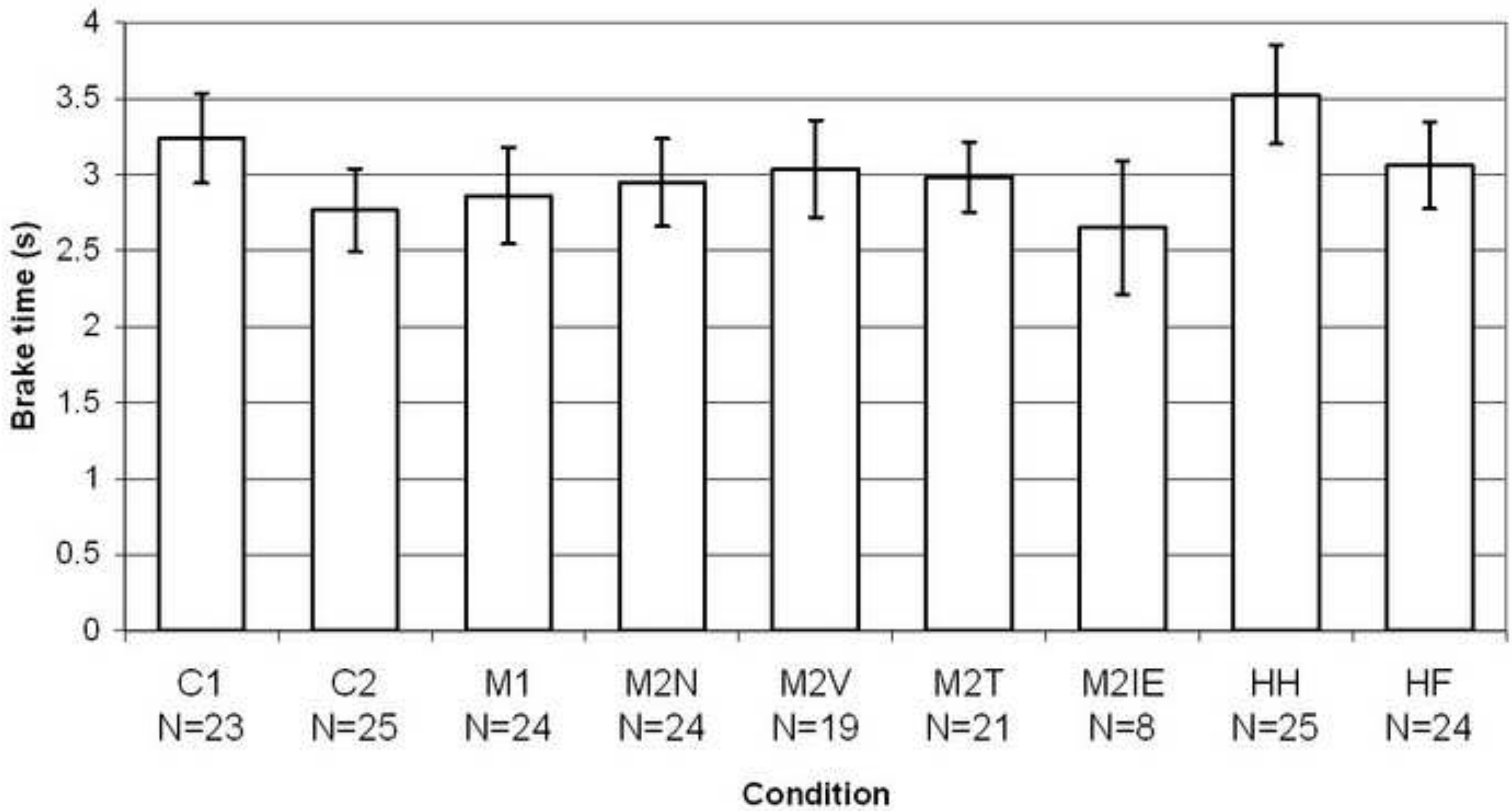

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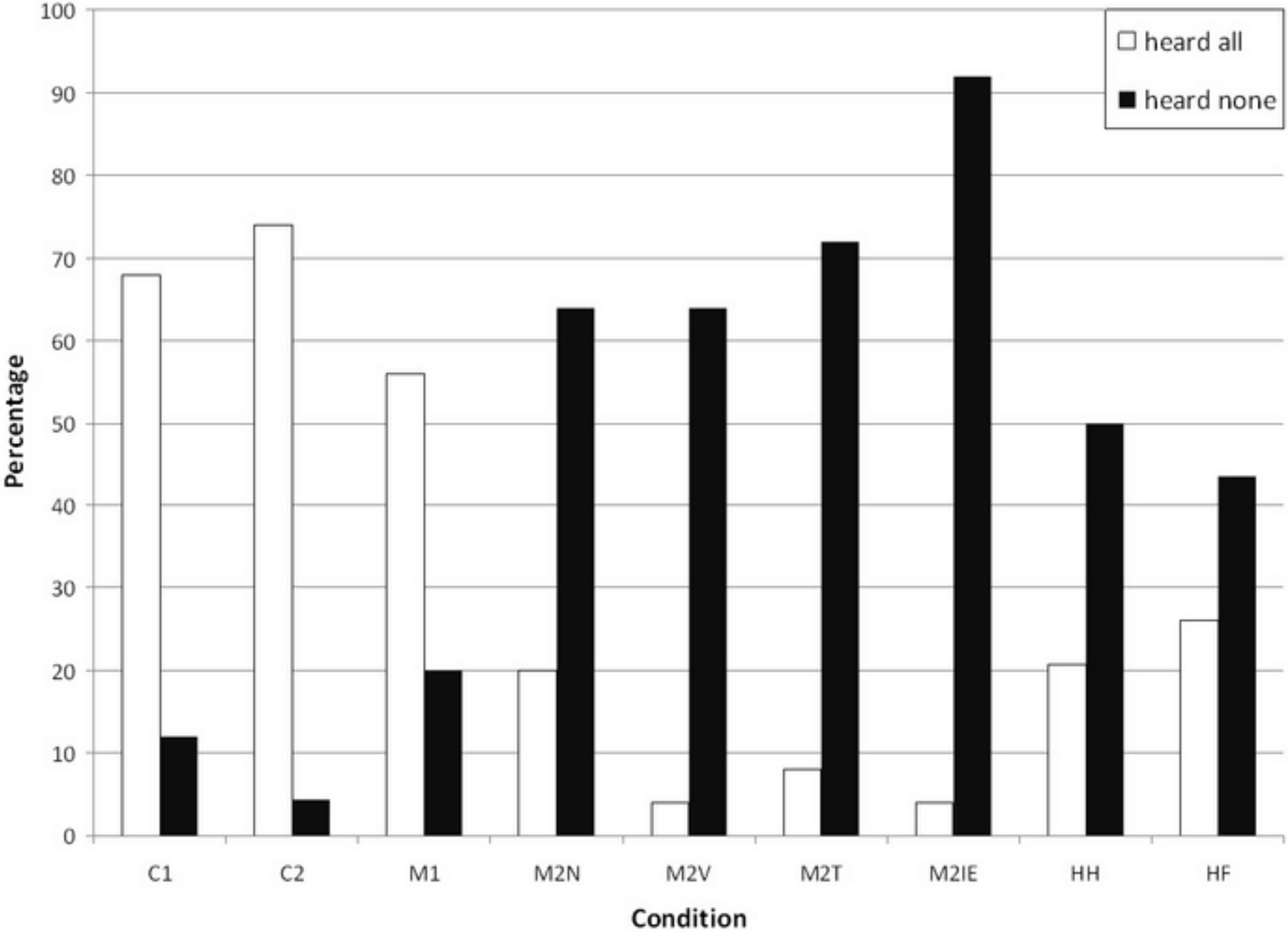

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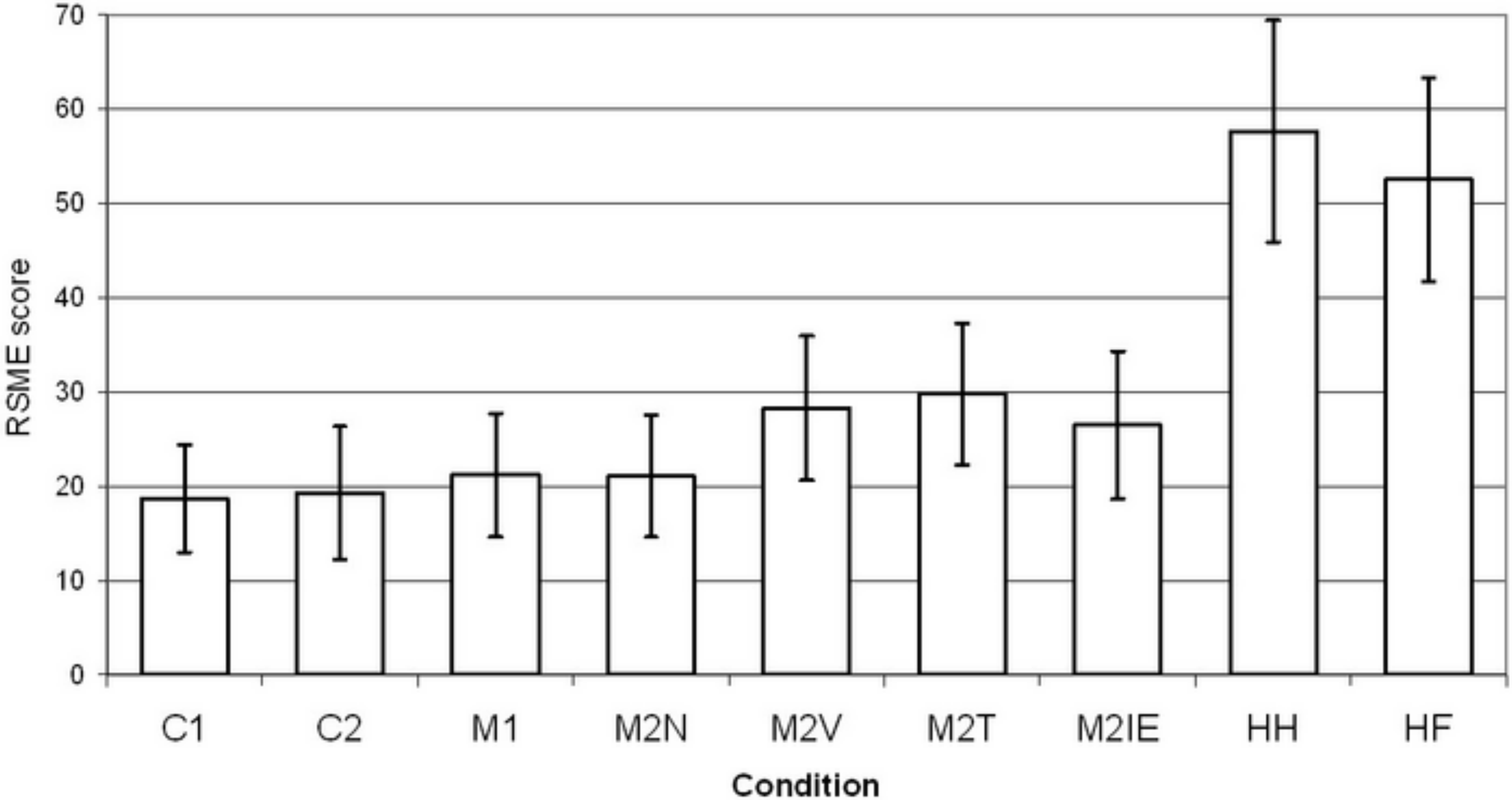

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