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Research paper

A field experiment on the impact of sounds from a jet-and-basin fountain on soundscape quality in an urban park

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HIGHLIGHTS

- Water sounds and ratings of soundscape quality were not directly related.
- Using water sounds to mask road-traffic noise is not simple and straight forward.
- Water sounds may affect the audibility of wanted as well as unwanted sounds.
- Water features ought to be pre-tested before constructed.

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ABSTRACT

A field experiment was conducted to explore whether water sounds from a fountain had a positive impact on soundscape quality in a downtown park. In total, 405 visitors were recruited to answer a questionnaire on how they perceived the park, including its acoustic environment. Meanwhile the fountain was turned on or off, at irregular hours. Water sounds from the fountain were not directly associated with ratings of soundscape quality. Rather, the predictors of soundscape quality were the variables “Road-traffic noise” and “Other natural sounds”. The former had a negative and the latter a positive impact. However, water sounds may have had an indirect impact on soundscape quality by affecting the audibility of road-traffic and natural sounds. The present results, obtained in situ, agree with previous results in soundscape research that the sounds perceived—particularly roadtraffic and natural sounds—explain soundscape quality. They also agree with the results from laboratory studies that water sounds may mask road-traffic sounds, but that this is not simple and straight forward. Thus sound should be brought into the design scheme when introducing water features in urban open spaces, and their environmental impact must be thoroughly assessed empirically.

1. Introduction

Water features are well-acknowledged as an important element of the urban environment, particularly in urban open spaces (e.g., Booth, 1983; Burmil, Daniel, & Hetherington, 1999; Nasar & Lin, 2003; Whalley, 1988). Booth (1983) provides a general, theoretic approach to landscape architecture, including water features, whereas Burmil, Daniel, and Hetherington (1999) provide an extensive review of the literature on water in the landscape. Whalley (1988) adds to the discourse by a review of past and current practice with regards to water features in landscape architecture. Together these authors illustrate how central the visual aesthetic aspect of water features is in landscape architecture, although they also acknowledge the importance of water sounds. In contrast, Nasar and Lin (2003) conducted an empirical study to test some theoretic assumptions (e.g., Booth, 1983) about the visual impressions that water features may have on people. Thirty participants assessed five colour photographs of water from water features. The study revealed that the water features with several vertical jets or a mix of different kinds of moving water were most visually attractive. A surface of still water was less visually attractive, but rated as most calming. Falling or flowing water received the least favourable scores, both in terms of visual attractiveness

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and calming. Thus, typically the visual aesthetic qualities of water features are considered, although their impact on the acoustic environment as it is perceived or experienced and/or understood by people, in context, (i.e., the soundscape; cf. Axelsson, 2012a) is increasingly recognised (see e.g., Axelsson, 2011, 2012b).

It has been suggested that sounds from water features may improve the urban soundscape (e.g., Booth, 1983; Brown & Muhar, 2004; Brown & Rutherford, 1994; Perkins, 1973), in particular that water sounds may be used to mask unwanted background sounds, chiefly from road traffic. In addition, the sound of flowing water may be positive in itself. Because of their practical implications for urban planning and design, researchers have begun to investigate these suggestions empirically, primarily through laboratory studies.

By listening experiments, Jeon, Lee, You, and Kang (2010) found that stream and wave sounds were preferred to sounds generated by birds, wind, and the bell of a church when they were combined with the sound from road-traffic or construction sites. They also found that the water sounds should be similar or not less than 3 dB below the sound-pressure level of the road-traffic and construction sounds. In a more recent study Jeon, Lee, You, and Kang (2012) found that the psychoacoustic metric *sharpness* had a strong positive correlation coefficient with preference scores of water sounds combined with road-traffic sound. Watts, Pheasant, Horoshenkov, and Ragonesi (2009) have previously reported similar results with regards to *sharpness*. In addition, they reported that people perceive naturally sounding water as more tranquil than water sounds that appeared manmade.

Galbrun and Ali (2013) conducted a listening experiment to test the peacefulness and relaxation of various kinds of water sounds combined with the sound from dense road traffic. Stream sounds tended to be preferred to fountain sounds, which in turn were preferred to waterfall sounds. Like Jeon et al. (2010), they found that water sounds should be similar or not less than 3 dB below the sound-pressure level of road-traffic sound. However, they did not find the expected relationship with *sharpness*.

Rådsten-Ekman, Axelsson, and Nilsson (2013) conducted a listening experiment in order to explore how sounds of water, varying in degree of pleasantness, influence the overall pleasantness and eventfulness of acoustic environments dominated by road-traffic sound. They found that overall pleasantness increased when a highly pleasant water sound (sea waves) was added to the road-traffic sound. For less pleasant water sounds (stream or waterfall), no effect, or a decrease in pleasantness, was found. In addition, pleasant water sounds increased the perceived eventfulness.

Nilsson, Alvarsson, Rådsten-Ekman, and Bolin (2010) conducted two laboratory experiments in which they investigated to what extent sounds from the jet-and-basin fountain, recorded in the downtown park Mariatorget, in Stockholm, may mask road-traffic sounds, recorded in the same park. The first experiment showed that water sounds recorded close to the fountain partially masked background road-traffic sounds. The second experiment showed that it is easier to mask fountain sounds with road-traffic sounds, than the other way around. De Coensel, Vanwetswinkel, and Botteldooren (2011) showed that water sounds only reduced the loudness of road-traffic sound if the latter had low temporal variability, whereas adding bird sound substantially improved the pleasantness and eventfulness of soundscape even for road-traffic sound with high temporal variability.

In the present paper we extend this line of research and report the results from a field experiment in which we manipulated the acoustic environment in the park Mariatorget, in Stockholm, by turning its jet-and-basin fountain on or off at irregular hours. With the purpose to explore whether or not the water sounds from the fountain has a positive impact on the soundscape quality of the park (i.e., Good–Bad evaluation), we asked visitors to answer a questionnaire on how they perceived the park, including its acoustic environment. Thus, inspired by the notion that sounds from water features may improve the urban soundscape, we were interested in how water sounds from the jet-and-basin fountain in Mariatorget contributes to the soundscape quality in this urban park, in situ. Laboratory studies may provide a theoretic understanding of how water sounds may improve the urban environment, but for this knowledge to be useful in practice we also need to understand how to assess the environmental impact of water sounds in real life, from a user or visitor perspective.

2. Method

As stated above, soundscape research concerns how people perceive or experience and/or understand the acoustic environment, in context (cf. Axelsson, 2012a). In the present study, we measured soundscape in terms of the proportion of park visitors who rated the acoustic environment in specified ways (e.g., as 'good' or 'very good'). This approach allowed evaluation of how park visitors perceived the acoustic environment at various locations in the park.

2.1. Mariatorget

Mariatorget is a park located on the island Södermalm in downtown Stockholm, Sweden. The park is rectangular (130 m × 60 m) and surrounded by streets, lined with 5–7 storey buildings (Figs. 1 and 2). Traffic flows mainly on the two main streets along the short sides of the park. Hornsgatan, on the northern side of Mariatorget, is one of the main traffic arteries on Södermalm (Photograph B in Fig. 1 depicts a street view of Hornsgatan). At Mariatorget the traffic on Hornsgatan is restricted. The street has one lane in each direction, and the speed limit is 50 km/h. Still, the street is heavily trafficked (approximately 20000 vehicles every 24 h). St Paulsgatan, at the southern border of Mariatorget, is a one-way street, mostly used by residents, taxis and delivery services (approximately 3000–3500 vehicles every 24 h) (Photograph A in Fig. 1 depicts a street view of St Paulsgatan). The two by-streets, along the long sides of the park, are mostly used by residents for parking (Photographs C and D in Fig. 1 depicts street views of the west and east by-streets, respectively).

Two perpendicular footpaths, running through the middle of the park, divide Mariatorget into four rectangular grass areas (Fig. 2). Where the footpaths intersect, the jet-and-basin fountain 'Tors fiske' (Thor's fishing) is located. Tors fiske has an elliptic basin (21 m × 14.5 m), and three large and two smaller nozzles mounted on a group of three bronze statutes (Fig. 3). The centrepiece depicts the moment when Thor has caught the Midgård Serpent, and raises his hammer, Mjölnir, to destroy it. The centrepiece is flanked by two prehistoric lizards. One of the three large nozzles is located in the jaws of the Midgård Serpent (Enlargement B in Fig. 3), and the other two in the noses of the lizards (Enlargements A and C in Fig. 3). Each produces a single, concentrated jet of water. The two smaller nozzles are located in the nose of the Midgård Serpent, and sprays smaller jets (Enlargement B in Fig. 3).

Park benches are located around the fountain, as well as along the main footpath, which extends through Mariatorget in the north–south direction, between the two main streets. Close to St Paulsgatan, there is a small playground frequently visited by parents with small children (marked "Pg" in Fig. 2).

2.2. Acoustic measurements

During the study period, we measured the sound-pressure levels around the park. On both Hornsgatan and St Paulsgatan we mounted a measurement microphone on the façade of a building

Fig. 1. Street views of Mariatorget: St. Palausgatan (A), Hornstgatan (B), west-by street (C), east-by street (D). See the right panel of Fig. 2 for where the photographs were taken. (Photography by Östen Axelsson, © 2009.)

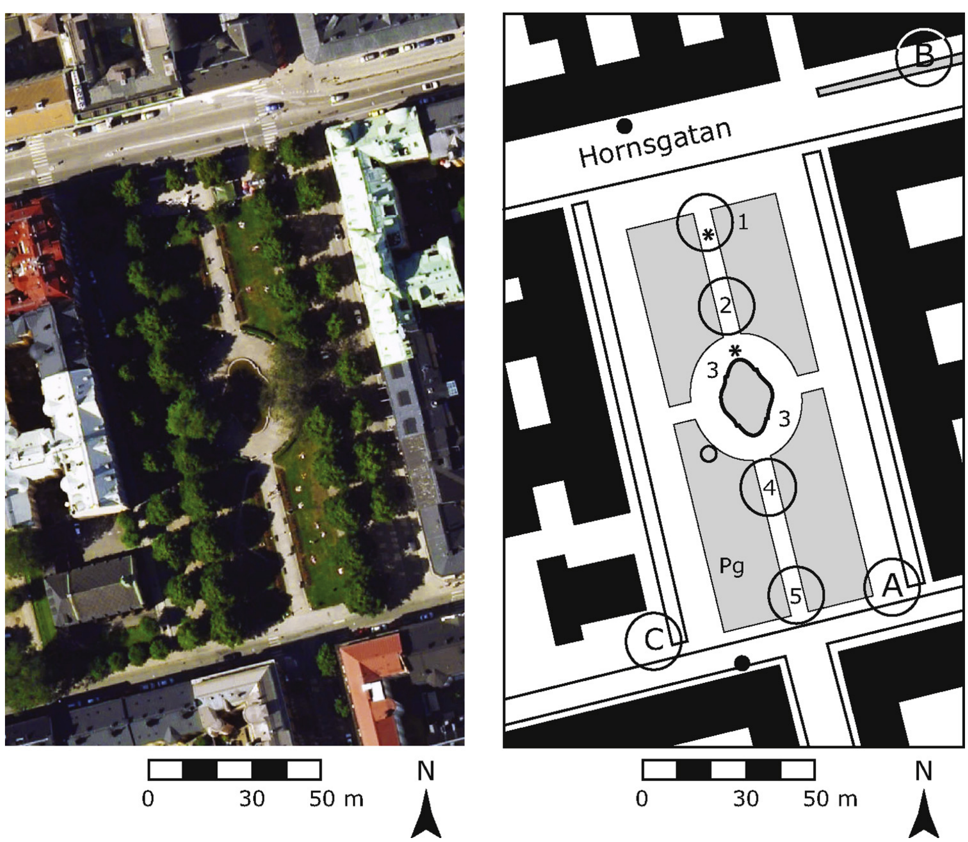

Fig. 2. Left panel: Aerial view of Mariatorget (courtesy of the City Planning Administration, City of Stockholm, © 2006). Right panel: Numbers (1–5) represent the five predefined zones of the park were the data was collected, while "Pg" marks the playground. The two filled black circles mark where the façade mounted measurement microphones of the sound-level meters were positioned during the study period. The open black circle by Zone 3 marks where the third sound-level meter was positioned in the park during data collection. The two asterisks in Zones 1 and 3 mark were acoustic measurements were conducted in June 2008. Letters (A–C) mark where the photographs in Fig. 1 were taken. (Photographs A and D at Position A, Photograph B at Position B, and Photograph C at Position C.)

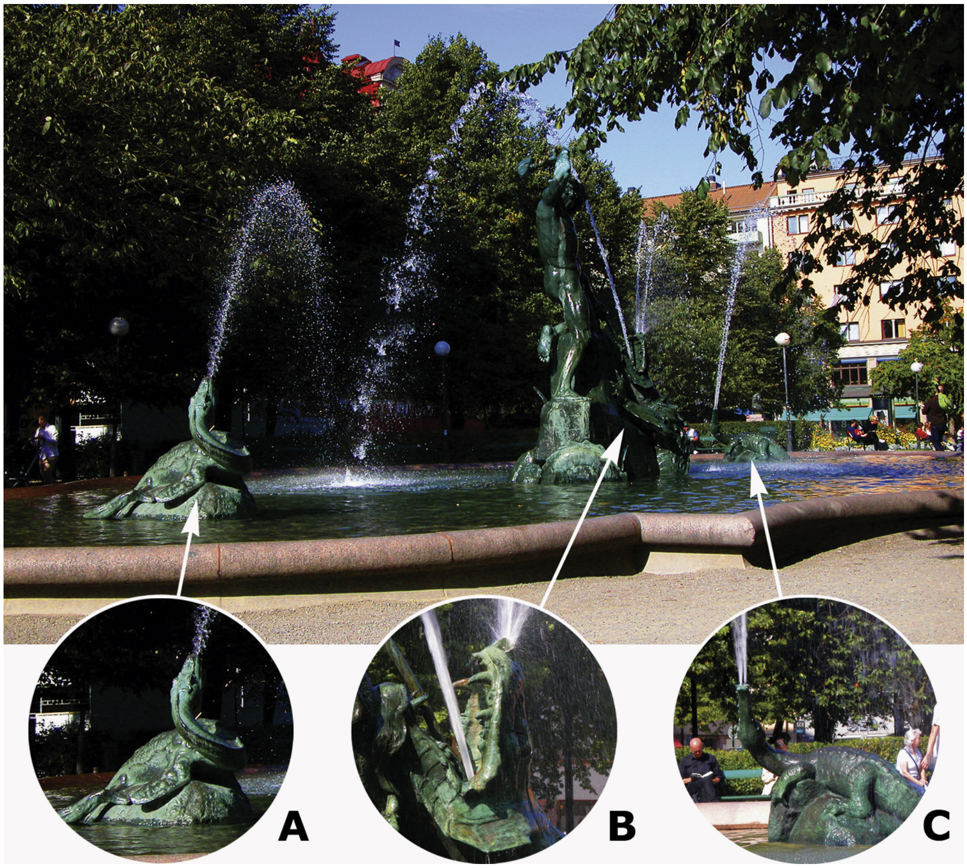

Fig. 3. The jet-and-basin fountain 'Tors fiske' (Thor's fishing) by Anders Wissler (1903). The view is facing north towards Horsgatan in the background. The three circular enlargements (A–C) point out the positions of the fountain nozzles. Enlargements A–C depicts the three large nozzles and Enlargement B the two small nozzles. (Photography by Östen Axelsson, © 2009.)

(10.30 and 9.85 m above the pavement, respectively; these measurement positions are marked with filled black circles in Fig. 2). Using sound-level meters with log capacity (Nor118, Norsonic) we started the measurements on the Monday the first week, and finished the measurements on the Thursday the second week of the study period. During this period the two sound-level meters registered the sound-pressure levels around the clock every 10 s, synchronised on the hour. This resulted in a large set of L_{10s} measurements for each sound-level meter (6 measurements every minute; 360 every hour; 8640 every 24 h). Please observe that the sound-level meters did not record the acoustic signal in WAV format, but as a set of preselected acoustic parameters: A- and C-weighted SPL and L_{eq}, as well as A-weighted L_{min} and L_{max} (fast).

We also used a sound-level meter (Nor118) in the park during data collection. The measurement microphone was mounted on a tripod 1.5 m above the ground, located by Zone 3, approximately 10 m from the fountain (open black circle in Fig. 2), and with the microphone membrane in the direction of the busiest street, Hornsgatan. Also this sound-level meter registered the sound-pressure levels every 10 s, synchronised on the hour.

For every participant, individually, we calculated the average sound-pressure levels as the arithmetic mean values of the 60 $L_{Aeq,10s}$ measurements obtained during the 10 min before the participant returned the completed questionnaire. For the two façade mounted microphones 6 dB were subtracted before this calculation, to correct the measurements for façade reflections (ISO, 2007). Table 1 presents the arithmetic mean values of all the average sound-pressure levels, as well as the minimum (lowest L_{min}) and maximum (highest L_{max}) sound-pressure levels, obtained for all participants during the 10 min before they returned the completed questionnaire, for each of the three sound-level meters separately.

As part of this research project, we used data from a large set of acoustic measurements collected in Mariatorget over an extended period in June 2008, one year before the present study (for further details, see Nilsson et al., 2010). The measurements included in the present paper were conducted during morning hours (09.00–11.00), at different days, and for approximately 20 min at different distances from the busiest street, Hornsgatan, along the main footpath in Mariatorget (equipment: Brüel & Kjær Type 4190 microphone, Type 2669 preamplifier, and Type 2690 NEXUS amplifier). Fig. 4 presents 1/3-octave-band frequency spectra recorded at 19 m distance from Hornsgatan (37 m to the north of the fountain side, in Zone 1) and at 55 m from Hornsgatan (1 m to the north of the fountain side, in Zone 3; asterisks in Fig. 2 mark the two measurement locations), when the fountain was turned on (circles in Fig. 4) and turned off (no symbol in Fig. 4). The fountain contributed to sound in the high frequency part of the spectrum,

Table 1
Arithmetic mean values of all average sound-pressure levels (dBA), as well as minimum (lowest L_{min}) and maximum (highest L_{max}) sound-pressure levels (dBA), obtained for all 405 participants during the 10 min before they returned the completed questionnaire, for each of three sound-level meters separately.

Location of sound-level meter	Mean	Minimum	Maximum
Hornsgatan	62.8	61.1	65.3
Mariatorget, Zone 3	60.4	55.5	65.1
St Paulsgatan	55.9	52.9	63.6

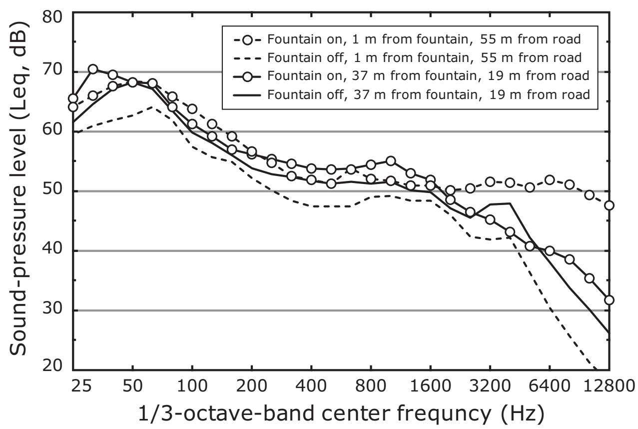

Fig. 4. 1/3-octave-band frequency spectra recorded at two locations in the park: (1) 19 m distance from Hornsgatan (37 m to the north of the fountain side, in Zone 1) and (2) at 55 m from Hornsgatan (1 m to the north of the fountain side, in Zone 3; asterisks in Fig. 2 mark the two measurement locations). Recordings were conducted when the fountain was turned on and when it was turned off. The acoustic measurements were conducted during morning hours (09.00–11.00) at different week-days. Recording time was approximately 20 min.

which is most clearly seen in the spectrum recorded at close distance to the fountain (see the two dashed lines in Fig. 4).

2.3. Handling loss of acoustic data

The three sound-level meters used in the present data collection were not completely reliable with regards to data storage, and all three meters failed to store data at some points. For Hornsgatan and St Paulsgatan we replaced missing data with the average values, calculated across the working days (Mondays–Fridays) of the study period. This is justified, because for each of these two measuring locations the 24 h sound-pressure-level profiles were very similar across the working days during the study period. Fig. 5 presents these average 24 h sound-pressure-level profiles for Hornsgatan (black line) and St Paulsgatan (grey line). Each data point represent the arithmetic mean value of $60 \times 8\,L_{\mathrm{Aeq,10s}}$ measurements obtained every 10 min, for the 8 full working days included in the study period.

For the sound-level meter in the park we replaced missing data with data from a similar measurement period as for the period that data was missing. That is, if data was missing an afternoon when the fountain was turned on, we used data from a similar measurement period as our estimates.

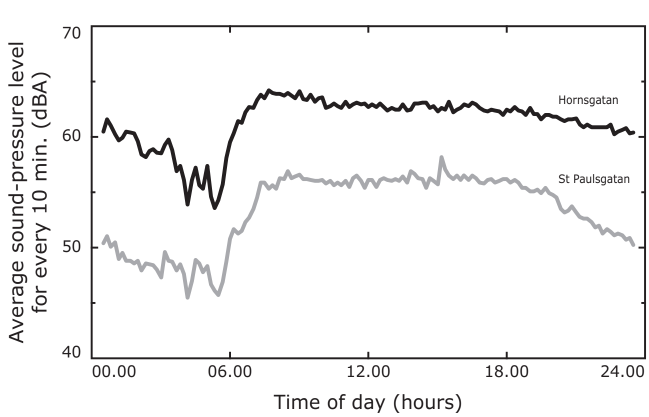

Fig. 5. Average 24 h sound-pressure-level profiles for Hornsgatan (black line) and St Paulsgatan (grey line). Each data point represent the arithmetic mean value of $60 \times 8\,L_{\mathrm{Aeq,10s}}$ measurements obtained every 10 min, for the 8 full working days (Mondays–Fridays) included in the study period.

2.4. Participants

In total, 405 visitors, 10–89 years old, were recruited as field-experiment participants (248 women, 157 men; M_{age} = 40.6 years, $\mathrm{SD}_{\mathrm{age}}$ = 18.1). Chiefly, we restricted participation to visitors who were 16 years or older. Three visitors younger than 16 years participated after being invited by a parent. Participants received a small monetary compensation.

2.5. Questionnaire

Human responses to the environment of Mariatorget were collected with the aid of a three-page questionnaire that included 18 questions in total. The questions concerned (a) individual background, such as year of birth, gender, living conditions, how frequently the participant visits parks and green areas, and the reason for visiting Mariatorget the current day, (b) how the participant perceived the overall quality of the park environment during the visit, and (c) how the participant perceived the acoustic environment of Mariatorget. The first two sections of the questionnaire, corresponding to the first two pages, were included mainly to mask the purpose of the study. Chiefly, the response formats were attribute scales and checklists, amounting to a total of 57 variables. Relevant questions and variables are reported in the result section below. The questionnaire was an improved version of questionnaires used in previous studies on parks and green areas in Greater Stockholm (Axelsson, Nilsson, & Berglund, 2009; Nilsson, 2007; Nilsson & Berglund, 2006; see also Axelsson, Nilsson, & Berglund, 2010).

2.6. Quasi experimental design

Because we were interested in understanding whether or not the water sounds from the fountain contribute to the soundscape quality of the park, and that previous studies have indicated that soundscape quality is dependent on the sounds perceived, particularly on the perceived magnitude of road-traffic and natural sounds (e.g., Axelsson et al., 2010; Lavandier & Defréville, 2006; Nilsson & Berglund, 2006; Nilsson et al., 2010), we divided the park in 5 zones along the main footpath (see Fig. 2). Zone 1 was closest to the busiest street, Hornsgatan. Zone 3 was located in the middle of the park, at an equal distance from the two main streets, and enclosing the fountain. Zone 5 was closest to the second busiest street, St Paulsgatan, on the far side of the park, away from Hornsgatan. In this way the 5 zones represent gradients of road-traffic and fountain sounds.

Based on the acoustic measurements conducted in June 2008, we attempted to select the five zones in such a way that the perceived magnitude of road-traffic and fountain sounds should be as equal as possible, and therefore well balanced, in the two intermediate zones, 2 and 4. This means that visitors in Zones 2 and 4 should perceive the road-traffic and fountain sounds as equality loud in these two zones, separately. Road-traffic sounds should dominate in Zones 1 and 5, whereas sounds from the fountain should dominate in Zone 3. With such a balanced mixture of road-traffic and fountain sounds, across the five zones, we would be able to measure the environmental impact of these two sound sources, with regards to soundscape quality, in this real-life setting.

To meet the purpose of the study, to explore whether or not the water sounds from the fountain may have a positive impact on the soundscape quality of the park, we either turned the fountain on or off during data collection. Thus, we created a 5 (zones) × 2 (fountain on or off) experimental design (i.e., 10 experimental conditions). We calculated that it would be sufficient to collect 30 complete questionnaires per experimental condition in order to obtain reliable soundscape measurements and to meet the purpose of the

Table 2
Data collection design explaining during which working period the fountain in Mariatorget was turned on or off for the purpose of the present study.

	Working period	Day of data collection			
		1	2	3	4
Before lunch	1	On	Off	On	Off
	2	Off	On	Off	On
After Lunch	3	On	Off	Off	On
	4	Off	On	On	Off

study. Nevertheless, in order to obtain an even number of questionnaires, and to safeguard against incomplete data, we decided to collect 40 independent questionnaires per experimental condition, and thus 400 questionnaires in total. Calculations revealed that we could collect all the 400 questionnaires in four days—100 questionnaires per day.

In designing the study we assumed that the road-traffic intensify would differs before and after lunch in a day, and also from one day to another. Therefore, in order to prevent potential variations in the background sounds from interfering with the purpose of the study we decided to counterbalance at what time of the day the fountain was turned on or off. As a result, we divided each day in four working periods—two before and two after lunch—with the fountain either turned on or off (Table 2). In each of the four working periods of a day we needed to collect 25 questionnaires, evenly distributed across the 5 predefined zones of the park (i.e., 5 questionnaires from each of the 5 zones of the park, per working period).

2.7. Procedure

The data was collected the second and third week of June 2009, during days with no or negligible rain. Rain—a water sound—would have interfered with the purpose of the study.

At any time, three assistants were working together with the data collection, starting at 09.30 a.m. when the morning traffic had settled after peak hour. In every working period the assistants worked through the 5 predefined zones of the park in an as irregular order as possible. However, to avoid biased responses from visitors who had seen the assistants turning the fountain on or off, the assistants often had to finish the data collection in Zone 3, where the fountain was located. The duration of each of the four working periods of the day depended on the time it took to collect 25 questionnaires (typically 1–1.5 h; 2 h at one occasion). The more visitors, the faster it was. This was usually the case on sunny days. The hours of the working periods were typically 09.30–11.00, 11.00–12.30, 13.30–15.00, and 15.00–16.30.

Visitors who seemed to have time to fill in a 5-min questionnaire were approached and asked to participate. These were usually persons who walked slowly through the park, or sat on a park bench, whereas people who walked like in a hurry, jogged or rode a bike were disregarded. During data collection the assistants also learned to be restrictive with visitors with small children, because the children often interfered with the study. For example, a few visitors with small children, following the child, wandered away into another zone from where they started to fill in the questionnaire. In these cases the zone data was changed to the zone where the questionnaire was finished, because the questions about the soundscape—related to the purpose of the study—were last in the questionnaire. On average, a participant needed 8 min to complete the questionnaire (Range: 3–25 min). In order to obtain independent data, no participant was allowed to take part more than once in the study.

When approaching a visitor the assistant informed that he or she worked for Stockholm University in collaboration with the City of Stockholm on a study on how visitors experience Mariatorget. The scientific purpose of the study, whether or not the water sounds from the fountain has a positive impact on the soundscape quality of the park, was never revealed to any participant.

When the participant returned the questionnaire, the assistant flipped it though to ensure that the participant had not accidently missed any questions. If so, the participant was asked if he or she was willing to answer the remaining questions and complete the questionnaire. Finally, the participants were offered a small monetary compensation. However, some participants did not want any compensation, and occasionally a participant returned the questionnaire without the assistant having time to screen it before the participant left the park. This led to some internal loss of data.

3. Results

Below we report results that are central to the purpose of the study, to explore whether or not the water sounds from the fountain has a positive impact on the soundscape quality of the park. Other analyses than those reported below were conducted, but the results were either not statistically significant, found irrelevant with regards to the purpose of the study, or beyond the scope of the present paper.

3.1. Data quality

Thanks to the procedure of screening the questionnaires on return, the qualified majority of the questionnaires were complete. Only 71 missing data values were recorded, to be compared with the total of 23085 data values (57 variables × 405 participants).

Among the participants, 5 were initially noted to provide potentially unreliable responses. For example, they may have found it difficult to understand spoken Swedish or the assistants' instructions (therefore 405 instead of 400 participants). During the data collection the assistants marked these 5 questionnaires to indicate that they needed to be checked. Nevertheless, all 405 will remain in the set of data, because data screening did not reveal anything unusual. Thus, the quality of our data was good, and all 405 collected questionnaires can be used without imputing data in the place of missing values.

3.2. Distribution of participants across experimental conditions

Because the participants in the present study were visitors who were recruited as they passed or uphold themselves in one of the 5 zones of the park, and not a fixed panel of judges who assessed the soundscape quality of the park under all the 10 experimental conditions, there is a risk for recruitment bias. To check the potential size of this risk, we conducted a series of analyses in which we investigated the relationship between the 10 experimental conditions and the individual background variables of the participants. Most of these variables were considered as nominal. For this reason, mainly Chi-Square analysis was used.

There were no statistically significant relationships between the 10 experimental conditions and gender ($\chi^2_9 = 12.73$, $p = 0.175$), kind of residence ($\chi^2_{27} = 31.86$, $p = 0.238$), whether the participants lived in Stockholm or in another council area in Sweden ($\chi^2_9 = 13.25$, $p = 0.151$), or how often the participants visited parks or green areas to relax ($\chi^2_{27} = 32.27$, $p = 0.222$). Neither did the analyses reveal any such relationships for whether the participants arrived Mariatorget from home, work or another location ($\chi^2_{27} = 16.99$, $p = 0.932$), how long time it took for the participants to arrive Mariatorget from that location ($\chi^2_{27} = 27.16$, $p = 0.455$), nor

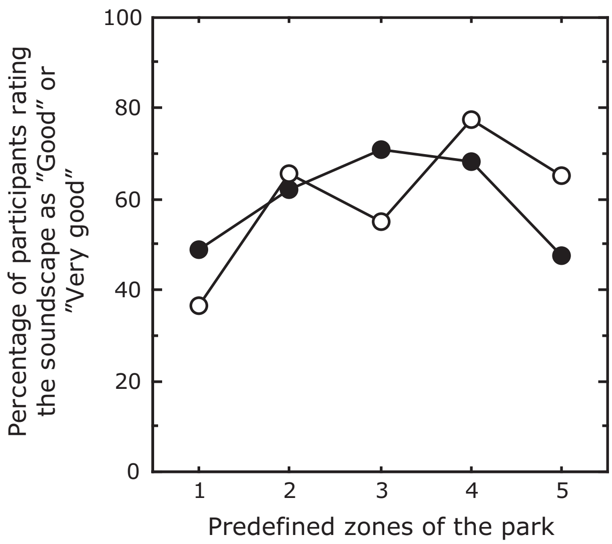

Fig. 6. Percentage of participants who marked the response categories "Good" or "Very good" with regards to soundscape quality, distributed across the five predefined zones of the park, and divided on whether the fountain was turned on ● or off ○.

how often the participants used to visit Mariatorget ($\chi^2_{36} = 25.34$, $p = 0.908$).

Two of the background variables, year of birth and the number of minutes spent in Mariatorget, were of ratio scale type. For each of these two variable a 5 (zones) × 2 (fountain on or off) ANOVA for independent measures was conducted. The number of minutes the participants had spent in Mariatorget when answering the questionnaire was unrelated to the 10 experimental conditions. No main effect was found for the 5 zones ($F_{4,394} = 0.89$, $p = 0.469$), for whether the fountain was turned on or off ($F_{1,394} = 1.28$, $p = 0.258$), nor was there any interaction effect ($F_{4,394} = 1.21$, $p = 0.308$). On the other hand, for the year of birth there was a statistically significant main effect for the 5 zones ($F_{4,394} = 3.39$, $p < 0.01$), but no main effect for whether the fountain was turned on or off ($F_{1,394} = 0.95$, $p = 0.331$), nor was there any interaction effect ($F_{4,394} = 2.11$, $p = 0.078$). Post-hoc tests, such as Fisher's PLSD, showed that the main effect for the 5 zones arose because, chiefly, the visitors recruited in Zone 3, where the fountain was located, where on average older than the visitor in the four other zones of the park.

Taken together the analyses of the individual background variables show that there are no reasons to suspect that there was any bias in the recruitment of the participants. Consequently, it is unlikely that the method of recruiting visitors in the park have affected the results of the study. That visitors recruited in Zone 3 were on average older than visitors in the other four zones is of limited importance, because this tendency was true regardless of whether the fountain was turned on or off. Nevertheless, we controlled for the year of birth in the statistical analysis reported in Section 3.6, below.

3.3. *Impact of fountain sounds on soundscape quality*

To measure soundscape quality, the participants were asked to indicate, on a 5-point ordinal category-scale, whether they found the surrounding acoustic environment of Mariatorget: "Very good", "Good", "Neither good nor bad", "Bad", or "Very bad". We calculated the percentage of participants who marked the response categories "Good" or "Very good". Fig. 6 presents this value, distributed across the five zones of the park, and divided on whether the fountain was turned on or off, that is, across our ten experimental conditions.

Fig. 6 shows that when the fountain was turned on (filled circles) the participants who visited the park at these times scored the soundscape quality of the park as better the further away from the two main streets (Zones 1 and 5) and closer to the fountain (Zone 3) they were. On the other hand, when the fountain was turned off (open circles) the participants tended to score the soundscape quality as better the further away they were from the busiest street, Hornsgatan (Zone 1). The drop in Zone 5 under this condition is probably a result of the proximity to St Paulsgatan. The lower response to soundscape quality in Zone 3 when the fountain was turned off compared to when it was turned on might be explained by dissatisfaction among the visitors that the fountain was turned off. From spontaneous comments to the assistants during data collection it seems that visitors expected the fountain to be on, and for several of the visitors the fountain seems to have been one of the reasons for visiting Mariatorget. A few visitors expressed irritation when the assistants turned the fountain off, and at least one visitor left the park in anger. Based on the definition of 'soundscape' presented in the introduction, we did not control for emotional factors or attitudes to the fountain in the statistical analysis reported in Section 3.6, because we regard these as inseparable aspects of soundscape and soundscape quality. However, we controlled for the distance to the fountain (Zone 3), as well as the distance to Hornsgatan (Zone 1).

3.4. *Relationship between "Water sounds from fountain" and "Road-traffic noise"*

Besides measuring soundscape quality, we asked the participants to indicate to what extent they perceived sounds from five different sound sources: "Road-traffic noise", "Other kind of noise" (i.e., other than road traffic), "Sounds from human beings", "Water sounds from fountain", and "Other natural sounds" (i.e., other than water sounds from the fountain). They indicated their responses on a 5-point ordinal category-scale: "Do not hear at all", "Hear a little", "Hear some", "Hear a lot", and "Dominates completely". For each of the five sound sources, we calculated the percentage of participants who marked the categories "Hear a lot" or "Dominates completely". The left panel of Fig. 7 presents this value for "Road-traffic noise" (squares) and "Water sounds from fountain" (circles), distributed across the five zones of the park, and divided on whether the fountain was turned on (filled symbols) or off (open symbols).

Fig. 7 suggests auditory masking effects (see e.g., Durlach et al., 2003; Moore, 1995; Watson, 2005). In Zone 3 the masking of road-traffic sounds is evident (cf. dashed lines in Fig. 4). Fountain sounds dominated when the fountain was turned on, and fewer participants indicated that road-traffic sounds were dominant when the fountain was turned on, compared to when it was turned off. In comparison, the participants who visited Zone 1 when the fountain was turned on indicated that they heard less road-traffic sounds compared to participants who visited this zone when the fountain was turned off. Because the visitors in Zone 1, in both conditions (fountain turned on or off), indicated that the perceived magnitude of road-traffic sounds was stronger than the perceived magnitude of fountain sounds, this effect may be attributed to the informational content of the soundscape. Possibly the participants who visited Zone 1 when the fountain was tuned on paid more attention to the fountain sounds than to the road-traffic sounds, and consequently gave lower scores to road-traffic sounds than the participants who visited Zone 1 when the fountain was turned off. The opposite effect is suggested in Zone 5, where the participants indicated that the magnitude of road-traffic sounds was stronger when the fountain was turned on than when it was turned off. Based on our acoustic measurements, we can exclude the possibility that the road traffic was systematically more or less intense

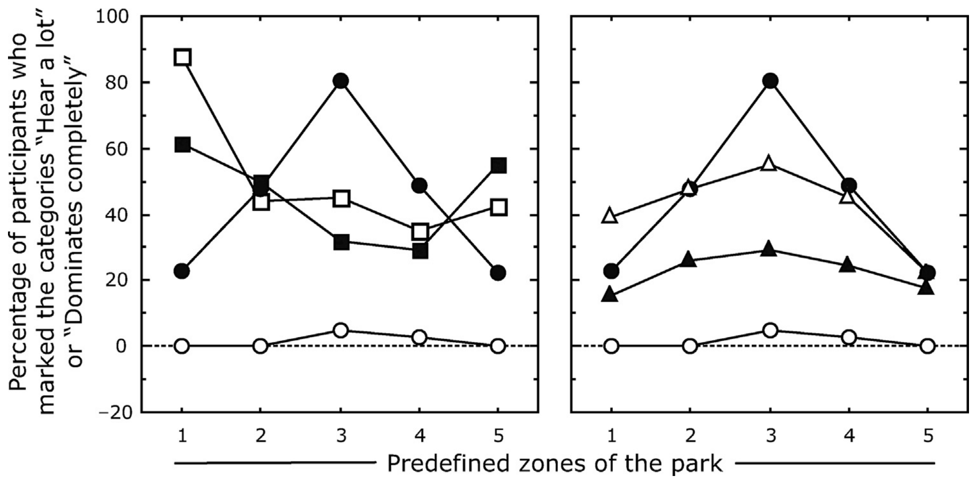

Fig. 7. Percentage of participants who marked the response categories "Hear a lot" or "Dominates completely" for "Water sounds from fountain" ● and "Road-traffic noise" ■ (left panel), as well as, "Water sounds from fountain" ● and "Other natural sounds" ▲ (right panel), distributed across the five predefined zones of the park. Filled symbols (●■▲) represent when the fountain was turned on, and open symbols (○□△) represent when the fountain was turned off.

at the hours the fountain was turned on. Presumably, the responses obtained in Zone 5 may be attributed to target-masker confusion (Durlach et al., 2003; Watson, 2005). That is, supposedly participants in Zone 5 partly mistook the faint fountain sounds for distant road-traffic sounds from Hornsgatan, which they were able to see in the background. We return to this observation in the discussion below.

3.5. Relationship between "Water sounds from fountain" and "Other natural sounds"

Sounds from the fountain did not only mask the road-traffic sounds, but also natural sounds. We did not ask the participants specifically about what natural sounds they heard besides the water sounds from the fountain, but this would likely be wind in vegetation and chirping birds. Mariatorget is especially known for its population of house sparrows who like to hide in the hedge that surrounds Zone 3.

The right panel of Fig. 7 presents the percentage of participants who marked the categories "Hear a lot" or "Dominates completely" for "Water sounds from fountain" (circles) and "Other natural sounds" (triangles), distributed across the five zones of the park, and divided on whether the fountain was turned on (filled symbols) or off (open symbols). It suggests that the sounds from the fountain served as a masker of other natural sounds throughout the park, except in Zone 5 furthest away from the busiest street. This is indicated by the vertical distance between the two graphs representing the perceived magnitude of other natural sounds when the fountain was turned on (filled triangles) and when the fountain was turned off (open triangles). It is only the sounds from the fountain that can explain these results, because this is the only sound source in the park that was varied systematically.

3.6. Road-traffic and natural sounds predicted soundscape quality

In order to explore what factors may predict soundscape quality, we conducted a stepwise binary logistic regression analysis (SPSS 21.0 for Windows, using the default settings). First, we transformed the soundscape quality values into a binary variable by assigning the number '1' to the participants who market the two response categories "Good" and "Very good", representing 'High soundscape quality' (240 participants), and the number '0' to the participants who market the remaining response categories "Neither good nor bad", "Bad" and "Very bad", representing 'Low soundscape quality' (163 participants). Two participants were excluded because of missing data. For both these groups 50% visited the park when the fountain was turned on and 50% when the fountain was turned off ($\chi^2_1 = 0.004$, $p = 0.952$), which means that whether the fountain actually was turned on or off during their visit did not influence the participants' judgments of the soundscape quality of the park.

We explored what factors may predict whether a participant belong to the group 'High soundscape quality' or 'Low soundscape quality', by regressing the binary soundscape quality variable on other variables, in various combinations. Below we report the most informative results, based on a stepwise analysis of three successive models.

As reported in Section 3.2, participants recruited in Zone 3 of the park were older than the participants recruited in the other zones. In Section 3.3, we showed that there were large differences in soundscape quality between the different predefined zones of the park, both in terms of the distance to the fountain in Zone 3, and in terms of the distance to Hornsgatan (see Fig. 6). In order to control for these factors, we created a new variable called 'Distance to fountain' (Zone 3 = 0; Zones 2 and 4 = 1; and Zones 1 and 5 = 2). Then we entered 'Year of birth' and 'Distance to fountain' together with 'Distance to Hornsgatan' (Zone 1 = 1, Zone 2 = 2, etc.) as predictors in our first model. Table 3 presents the logistic-regression coefficient (B), Wald test, and odds ratio for each of the predictors of the first model [$\chi^2_3 = 13.16$, $p < 0.01$; $R^2 = 0.03$ (Cox & Snell) 0.05 (Nagelkerke)]. 'Distance to fountain' made a statistically significant and negative contribution to soundscape quality over and above the intercept, whereas the logistic-regression coefficients for 'Distance to Hornsgatan' and 'Year of birth' where not statistically significant. Thus, when controlling for the year of birth of the participants, the probability for a participant to belong to the group reporting a high soundscape quality increased the closer to the fountain, and the further away from the two main streets, the participant was located when answering our questionnaire.

Table 3
Logistic regression statistics for predictors of soundscape quality (first model).

Predictor	B	Wald χ^2_1	p	Odds ratio
Year of birth	0.01	2.09	0.148	1.01
Distance to fountain	−0.42	8.26	0.004	0.66
Distance to Hornsgatan	0.13	3.08	0.079	1.14
Intercept	−16.32	1.98	0.159	0.00

Table 4
Logistic regression statistics for predictors of soundscape quality (second model).

Predictor	B	Wald χ^2_1	p	Odds ratio
Year of birth	0.01	1.83	0.176	1.01
Distance to fountain	−0.41	7.85	0.005	0.66
Distance to Hornsgatan	0.13	3.13	0.077	1.14
Average sound-pressure level (dBA)				
Hornsgatan	−0.01	0.01	0.936	0.99
St Paulsgatan	0.03	0.16	0.690	1.03
Mariatorget, Zone 3	−0.02	0.21	0.648	0.98
Intercept	−15.21	0.92	0.337	0.00

In the second step, of this reported analysis, we added our three sound-pressure-level measurements from Hornsgatan, St Paulsgatan and Zone 3 of Mariatorget, obtained for each participant individually during the 10 min before they returned the completed questionnaire (see Section 2.2 of the present article). Table 4 presents the logistic-regression coefficient (B), Wald test, and odds ratio for each of the predictors of the second model [$\chi^2_6 = 13.42$, $p = 0.04$; $R^2 = 0.03$ (Cox & Snell) 0.05 (Nagelkerke)]. As for the first model 'Distance to fountain' made a statistically significant and negative contribution to soundscape quality over and above the intercept. However, none of the logistic-regression coefficients for any of the other variables were statistically significant. Thus, soundscape quality was independent of the sound-pressure levels.

As the third and last step, of this reported analysis, we added the five 'sound-source-identification' variables "Road-traffic noise", "Other kind of noise", "Sounds from human beings", "Water sounds from fountain", and "Other natural sounds". Table 5 presents the logistic-regression coefficient (B), Wald test, and odds ratio for each of the predictors of the third model [$\chi^2_{11} = 82.43$, $p < 0.001$; $R^2 = 0.19$ (Cox & Snell) 0.26 (Nagelkerke)]. "Road-traffic noise" and "Other natural sounds" made statistically significant contributions to soundscape quality. Importantly, none of the logistic-regression coefficients for any of the other variables, including 'Distance to fountain', were statistically significant in the third model. Thus, perceived magnitude of road-traffic sound was a negative component of the soundscape, whereas perceived magnitude of natural sounds was a positive component, regardless of in which of Zones 1–5 the participants where located when rating the soundscape quality of the park. As indicated in the beginning of this section, and validated by the binary logistic regression analysis, water sounds from the fountain had no direct impact on the participants' ratings of the soundscape quality of the park.

Table 5
Logistic regression statistics for predictors of soundscape quality (third model).

Predictor	B	Wald χ^2_1	p	Odds ratio
Year of birth	0.01	2.66	0.103	1.01
Distance to fountain	−0.04	0.04	0.835	0.97
Distance to Hornsgatan	−0.01	0.02	0.894	0.99
Average sound-pressure level (dBA)				
Hornsgatan	0.20	1.05	0.304	1.22
St Paulsgatan	0.03	0.09	0.765	1.03
Mariatorget, Zone 3	−0.05	0.51	0.476	0.95
"Road-traffic noise"	−1.07	42.49	<0.001	0.34
"Other kind of noise"	−0.21	2.68	0.101	0.81
"Sounds from human beings"	0.13	0.79	0.373	1.14
"Water sounds from fountain"	0.11	0.60	0.438	1.11
"Other natural sounds"	0.33	6.47	0.011	1.39
Intercept	−31.50	2.77	0.096	0.00

The improvement in Chi-Square values show that the third model performed significantly better than the first two models (improvement from fist model: $\chi^2_8 = 69.28$, $p < 0.001$; improvement from the second model: $\chi^2_5 = 69.02$, $p < 0.001$). The third model was able to correctly classify 53% of the participants who reported a low soundscape quality and 80% of the participants who reported a high soundscape quality. The overall success rate of the model was 69%.

4. Discussion

We conducted a field experiment to explore whether or not the water sounds from the jet-and-basin fountain 'Tors fiske' in Mariatorget, a downtown park in Stockholm, Sweden, has a positive impact on the soundscape quality of this park. Our results show that the water sounds from the fountain had no direct impact on the participants' ratings of the soundscape quality of the park. Binary logistic regression analysis showed that there were two statistically significant predictors of soundscape quality: "Road-traffic noise" and "Other natural sounds". Perceived magnitude of road-traffic sounds had a negative impact, whereas perceived magnitude of natural sounds had a positive impact on soundscape quality (Table 5).

If the water sounds from the fountain had any impact on soundscape quality at all, it would be an indirect impact by affecting the audibility of other sounds. Our results show that water sounds from the fountain did mask both road-traffic sounds and natural sounds in the park, particularly in Zone 3, where the fountain was located (Fig. 7). Because road-traffic sounds had a negative impact, masking of road-traffic sounds would likely be positive with regards to soundscape quality. The opposite would be true for natural sounds.

The results of this field experiment partly support the notion that sounds from water features may improve the urban soundscape through masking of road-traffic sounds. However, the relationship between whether the fountain was turned on or off and the perceived magnitude of road-traffic sounds was complex (see left panel of Fig. 7). As mentioned in the results above, we believe that this complexity may be attributed to auditory masking, both in the form of 'energetic' and 'informational' masking (e.g., Durlach et al., 2003; Moore, 1995; Watson, 2005).

Energetic masking means that a masking sound makes a target sound inaudible (complete masking) or less loud (partial masking) by decreasing the signal-to-noise ratios in the frequency regions surrounding the target sound at the basilar membrane (Moore, 1995). In Fig. 7 energetic masking is evident in Zone 3 of the park where the fountain was located. The participants who visited this zone when the fountain was turned on gave lower scores to the perceived magnitude of road-traffic sound compared to the participants who visited this zone when the fountain was turned off.

Informational masking is a result of neural functions at higher levels of auditory processing (Durlach et al., 2003). An example of informational masking would be confusion due to the auditory similarity between the target and masker sounds, such as water and road-traffic sounds (cf. Nilsson et al., 2010). If a part of the masking sound (e.g., water) is confused with the target sound (e.g., road traffic), then the overall masking would decrease. Conversely, if part of the target sound (e.g., road traffic) is confused with the masking sound (e.g., water), then the overall masking would increase.

The participants who visited Zone 1 of the park when the fountain was turned on gave lower scores to the perceived magnitude of road-traffic sounds compared to the participants who visited Zone 1 when the fountain was turned off. Because the fountain is the only source that was varied systematically in the study and no other measured factor can explain this effect, the result indicates that the fountain had a masking effect, although perceived magnitude of water sounds from the fountain received lower scores than the road-traffic sounds. Thus, this effect cannot be a matter of energetic masking, but is attributed to the informational content of the soundscape. As stated in the result section, possibly the participants who visited Zone 1 when the fountain was turned on paid more attention to the fountain sounds than to the road-traffic sounds, and consequently gave lower scores to road-traffic sounds than the participants who visited Zone 1 when the fountain was turned off. In contrast, the participants who visited Zone 5 of the park when the fountain was turned on gave higher scores to the perceived magnitude of road-traffic sounds compared to those who visited this zone when the fountain was turned off. Again it is only the sounds from the fountain that can explain this effect, and it is probably a result of partially confusing the water sounds from the fountain (masker) with road-traffic sounds (target). In this case the overall masking is not only decreasing, but negative.

The results show that there is no simple 1:1 relationship between the acoustic environment and how people perceive it. This must be taken into consideration when planning or designing urban open spaces. It would be wrong to assume that erecting a fountain in an urban open space will simply do wonderful things for the acoustic environment. It might as well create something as complex as the results presented in the left panel of Fig. 7. Because the fountain is the only source that was varied systematically in the study, our best explanation is that it is the water sounds from the fountain that caused this complexity, by auditory masking.

The complexity described here did not prevent people from visiting the park. However, it indicates that there is room for fine-tuning and improvement of the soundscape quality of the park. Based on our results, we have had a discussion with the City of Stockholm about the possibility to extend the present study and to re-tune the fountain in Mariatorget. They have expressed themselves cautiously supportive of this idea.

It could be argued that the complexity of our results with regards to perceived magnitude of road-traffic sounds is due to selection bias in the recruitment of our participants. However, our results from the analysis of the individual background variables, presented in Section 3.2, show that there is no foundation for such an objection. The binary logistic regression analysis presented in Section 3.6 supports this conclusion. In addition, proponents of selection bias would, for example, have to explain why the results for perceived magnitude of water sounds from the fountain, as well as for other natural sounds, seem logical (right panel of Fig. 7). If selection bias could explain the complexity of our results with regards to road-traffic sounds (left panel of Fig. 7), would it not be reasonable to expect that all of our results would have shown effects of this bias in the form of complexity? In our opinion, our results reflect the actual complexity of reality.

It could also be argued that emotions and attitudes to the fountain should be controlled for in our study, because else the results on soundscape quality reported in Fig. 6 would not represent a just assessment of the effect of the fountain itself. As we stated in the result section we regard emotions and attitudes as inseparable aspects of soundscape and soundscape quality. According to the definition we follow, 'soundscape' denotes the acoustic environment as perceived or experienced and/or understood by people, in context (cf. Axelsson, 2012a). The acoustic environment is regarded as a physical phenomenon whereas soundscape is psychological. The acoustic environment is measured by physical tools like a sound-level meter, whereas soundscape is measured through human perception of the acoustic environment.

Previous, as well as our own, results show that people dislike road-traffic sounds and prefer natural sounds. This effect is unrelated to sound-pressure levels, which means that natural sounds are preferred to road-traffic sounds also when the sound-pressure levels are equal. Possibly this is partly because people have a negative attitude to road-traffic and a positive attitude to nature. Their attitude to the sound source is an integrated part of their perception or experience and/or understanding of the acoustic environment, and thus the soundscape quality (cf. 'quality of life'; The WHOQOL Group, 1998).

In addition, it could be argued that visual aspects should have been included in the study as there might be audio-visual interactions with regards to the fountain. This is motivated because, as outlined in the introduction, water features are most often designed based on principles of visual aesthetics. So, to what extent can the visual impressions of water features account for soundscape quality?

Audio-visual interactions cannot be studied effectively in situ and would probably require yet another laboratory experiment. For example, it would of course not be practically possible to remove the fountain in Mariatorget in one experimental condition and place it back it in another, or to replace the fountain with another in order to study how absence or presence of the fountain, or how a different fountain would affect the soundscape quality in the park. We could have doubled the number of participants and randomly blindfolded half of them in order to explore audio-visual interactions. This might be a proposal to explore in future research that is specifically targeted at this issue. It is possible that visual impressions may influence soundscape quality, but it is not likely to have a dramatic effect (closing one's eyes does not change the soundscape substantially).

The principal idea behind our study was to bring our research out from the laboratory and conduct an exploratory study of a real fountain in a real location to learn more about assessment of soundscape quality in real life. We hope that our study will provide inspiration and contribute to the implementation of soundscape, for instance, in environmental impact assessments. We believe that it is valuable to base such assessments on the visitor's or user's perspective. Inevitably, this will lead to some restrictions and limitations, particularly with regards to the number of factors that may be kept under experimental control. On the other hand, field studies are associated with higher ecological validity than laboratory studies, that is, they have a stronger resemblance with reality.

Our results agree with previous findings in soundscape research that the most important factors contributing to soundscape quality is the sounds perceived, and particularly the perceived magnitude of road-traffic and natural sounds (Axelsson et al., 2010; Lavandier & Defréville, 2006; Nilsson & Berglund, 2006; Nilsson et al., 2010). Our results, obtained in situ, also agree with the still limited results from laboratory experiments that using water sounds in order to improve the urban soundscape by masking road-traffic sounds is possible, but not simple and straight forward (De Coensel et al., 2011; Jeon et al., 2010, 2012; Galbrun & Ali, 2013; Nilsson et al., 2010; Rådsten-Ekman et al., 2013; Watts et al., 2009).

To summarise the present state of the science, it is central to acknowledge that there are different kinds of water sounds, such as the sound of waves, streams, and waterfalls. These sounds vary in pleasantness (Rådsten-Ekman et al., 2013), and have different capacity to mask road-traffic sounds (De Coensel et al., 2011; Jeon et al., 2010, 2012; Galbrun & Ali, 2013; Nilsson et al., 2010; Rådsten-Ekman et al., 2013). It seems that the sound of waves is preferred to the sound of streams, which in turn is preferred to the sound of waterfalls (Jeon et al., 2010; Galbrun & Ali, 2013; Rådsten-Ekman et al., 2013). Rådsten-Ekman et al. (2013) showed that the sound of a waterfall in combination with road-traffic sound was perceived as less pleasant than the sound of road traffic alone. In addition, people perceive naturally sounding water as more tranquil than water sounds that appears manmade (Watts et al., 2009). In general, the capacity of water sounds to masks road-traffic sounds is limited (Galbrun & Ali, 2013; Nilsson et al., 2010) and only possible if the latter sound has low temporal variability (De Coensel et al., 2011). Finally, the water sounds should be similar or not less than 3 dB below the sound-pressure level of the road-traffic sounds (Jeon et al., 2010; Galbrun & Ali, 2013). To this we may now add that in real life the situation is far more complex than the situation created in a laboratory, and that water sounds may not only mask unwanted but also wanted sounds.

Collectively, the available literature on sounds from water features prove how central it is to bring sound into the design scheme when introducing water features in urban open spaces. In the same way as architects create virtual 3D models of their designs and test them with regards to various visual aspects, such as the effects of light and shadow, we would argue that it is equally important to pre-test the design of water features with regards to their auditory aspects. Initially, this can be done in a listening laboratory, playing back audio recordings either by headphones or loudspeakers. Nevertheless, the implication of the present study is that because the laboratory cannot equal real life, it is necessary to pre-test the design in the form of a prototype before the real thing is constructed, and to follow up the results when the water feature finally is in place. All pre-tests must include human listeners representing the end-users. It is central that the pre-tests include a variety of sounds that may occur in the intended location, distributed across the three main classes of sounds: technology (e.g., road-traffic and other kinds of noise), nature (e.g., water sounds from the fountain and other kinds of natural sounds), and humans (e.g., voices). Investigating potential masking effects would include testing the audibility of the different sounds in various combinations at authentic sound-pressure levels. It is vital to include a quality response, either in the form of overall soundscape quality (i.e., Good–Bad scale), or in the form of emotional responses, such as pleasantness and eventfulness (Axelsson et al., 2010; see also De Coensel et al., 2011; Rådsten-Ekman et al., 2013). The objective of this process would be to identify the appropriate water sounds for the water feature, both in terms of its character and in terms of sound level.

5. Conclusions

The main conclusions of the present study are:

(a) The sounds from the fountain in Mariatorget had no direct impact on the participants' ratings of the soundscape quality of the park.
(b) There were two statistically significant predictors of soundscape quality: "Road-traffic noise" and "Other natural sounds". Perceived magnitude of road-traffic sounds had a negative impact, whereas perceived magnitude of natural sounds had a positive impact on soundscape quality.
(c) If the water sounds from the fountain had any impact on soundscape quality at all, it would be an indirect impact by affecting the audibility of other sounds.
(d) The water sounds from the fountain did mask both road-traffic and natural sounds in the park, chiefly close to the fountain (i.e., in Zone 3). Because road-traffic sounds had a negative impact, masking of road-traffic sounds would likely be positive with regards to soundscape quality. The opposite would be true for natural sounds.

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