Supervised Group Training of Analogical Reasoning in Children with Cochlear Implants: No
Transfer Effects.

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Abstract

Analogue reasoning has been argued to be of importance for language development. Deaf and hard of hearing (DHH) children with cochlear implants (CI) are at risk of having language delays. The aim of the current study was therefore to investigate if the analogue reasoning and language ability of children with CI can be improved by means of cognitive training. Based on previous research the children trained, with supervision, in groups to increase the metacognitive aspect of the training. The results do not indicate any general effects of the training on the analogue reasoning ability of the children included in the current study. Furthermore, no evidence for a paradigmatic transfer of the training, resulting in improvements of language development, was found.

Keywords: inductive reasoning training, cochlear implant, children, far transfer

Word count: X

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Introduction

A majority of children with cochlear implants (CI) in Sweden rely on spoken communication. However, when children with CI reach school-age (~ age 6 in Sweden) a large percentage of them has spoken language delays (Geers, Moog, Biedenstein, Brenner, & Hayes, 2009). This is an issue as language ability is of importance when it comes to participating in lectures and interacting with peers. Intensive language training takes time and most training programs concentrate on specific language abilities (Lund & Douglas, 2016; for example: Mentzer et al., 2013). Therefore, these trainings may lead to improvement on the language skill being trained rather than to a general improvement in language ability. An alternative solution to improve spoken language ability might be to train those cognitive skills that underlie spoken language acquisition. One such skill is analogical reasoning (Behrens, 2009; Gentner & Namy, 2006; Tomasello, 2005). Analogical reasoning refers to the ability to find relationship patterns and to transfer those to new situations or objects (Gentner & Smith, 2012). When acquiring a language a child has to find patterns to build semantic categories and to learn the syntax of the language. Gentner and Namy (2006) summarize results indicating these abilities are associated with analogical reasoning skills. Behrens (2009) and Tomasello (2005) even argue that pattern finding is one of the core abilities needed for language acquisition.

The effects of cognitive training are usually measured by evaluating near as well as far transfer. Near transfer refers to improvements on the trained skill. This means near transfer of analogical reasoning training would be achieved if a child improved significantly on analogical reasoning tests due to the training. Far transfer on the other hand refers to improvements on other skills depending on the trained skill. Far transfer could be achieved via paradigmatic transfer. Paradigmatic transfer would be expected to occur if cognitive

training leads to an improvement in the understanding of the trained construct (Barkl, Porter, & Ginns, 2012; Roth-van der Werf, Resing, & Slenders, 2002). If this were the case, we would expect performance on all tasks influenced by the trained construct to be improved. In the example of analogical reasoning training this would mean that language ability should improve as well, as analogical reasoning has been found to be important for language acquisition (Gentner & Namy, 2006).

Analogical reasoning training has been found to lead to improvements in analogical reasoning ability (for a review see: Klauer & Phye, 2008). Studies by Marx (2006) and Marx, Keller, and Beuing (2010) even suggest a transfer effect of analogical reasoning training to language abilities. A study by Lenhard and Lenhard (2011) showed that even a computerized version of an analogical reasoning program (Lenhard et al., 2011) is effective. However, Klauer (1996) emphasizes that metacognitive (strategy) training is of importance for analogical reasoning training to be effective. Metacognitive training means that the children taking part in the training reflect on the strategy they used to solve a specific task and that they try to generalize this strategy to similar tasks.

A previous study from the authors of the current study showed that regardless of whether children used the computerized training by Lenhard et al. (20) alone or train together with a parent, the training did not lead to any improvements of analogical reasoning (Socher, Larsson, Wass, Ellis, & Lyxell, n.d.). It might be the case that the metacognitive aspect of the training was not prevalent enough when the children trained at home or with a parent. Although the parents received instructions for the metacognitive training, the results indicated that the parents might have provided too much help for solving the tasks (Socher et al., n.d.). If the children did not have to come up with the solutions themselves, it is not surprising that no transfer effects to analogical reasoning training was found.

Marx et al. (2010) showed that having kindergarten teachers as supervisors during analogical reasoning training leads to training effects. This might be the case as kindergarten

74 teachers are more professional supervisors than parents. It might therefore be recommended
75 to have a teacher instead of a parent as a supervisor for the the training by Lenhard et
76 al. (2011). In addition, in the meta-analysis by Klauer and Phye (2008) it was shown that
77 one-to-one training of analogical reasoning had a smaller effect than training in pairs, small
78 groups and in classes. A reason for this might be that training in a group increases the
79 metacognitive aspect of the training as the children have to explain their answers to the other
80 children in the group.

81 In the current study we aimed to test a Swedish version of the computerized analogical
82 reasoning training developed by Lenhard et al. (2011) with children with CI. The training
83 was conducted in groups and was supervised by a teacher. Our aim was to evaluate if the
84 training leads to effects on analogical reasoning and if those effects transfer to language
85 ability. The current study was based on a small sample as we aimed to evaluate the potential
86 usefulness of a larger scale study of the program. Therefore, visual investigation of the data
87 was used instead of statistical testing.

88 **Research questions:**

- 89 1. Can analogical reasoning of children with CI be improved by means of cognitive
90 training when the training is conducted in a group and supervised by a teacher?
- 91 2. Does analogical reasoning training in a group, supervised by a teacher lead to far
92 transfer to language ability for children with CI?

93 **Methods**

94 **Participants**

95 Seven children with CI participated in the current study. They were all recruited from
96 a Swedish special school. For one of the children data is missing for one of the outcome
97 measures (Animalogica). Written consent was given by the caregivers of the children and the
98 study was approved by the Linköping Research Ethics Committee (dnr 2015/308-31).

Children and caregivers were informed that they could drop out of the study at any time without giving a reason. All children received stickers for their participation.

Material

A Swedish translation of the program “Denkspiele mit Elfe und Mathis” (Thinkgames with Elfe and Mathis, Lenhard et al., 2011) was used to train the children’s analogical reasoning ability. During baseline, pre-test and post-test, the children were tested on three analogical reasoning tasks: The Matrix test from the Wechsler Non-Verbal Scale of Ability (WNV) (Wechsler & Naglieri, 2007), Animalogica (Stevenson, Heiser, & Resing, 2013) and the verbal analogies test from the Illinois Test of Psycholinguistic Abilities 3 (ITPA-3) (Hammill, 2013). These tasks were used to measure the near transfer of the training. In order to measure the far transfer of the training to language ability, story comprehension (Bishop & Adams, 1992; Eldblom & Sandberg, 2011; Holck, Nettelbladt, & Sandberg, 2009), semantic fluency and phonemic fluency (Benton & Hamsher, 1976) were tested. These tests were chosen as both language comprehension (Lepola, Lynch, Laakkonen, Silvén, & Niemi, 2012) and the building of word categories (Gentner & Namy, 2006) have been suggested to be influenced by reasoning ability.

Analogical Reasoning Training. A Swedish translation of the “Denkspiele mit Elfe and Mathis” (Lenhard et al., 2011) was used for this study as a training program. This computer game is a modernized version of the analogical reasoning training program for 5 to 8 year old children originally developed by Klauer (1989). The training was incorporated into a story. The main characters of the game were two elves, Älvan and Mathis (Swedish version), who asked the children for their help on their search for the blue diamond of wisdom. This story line aimed to enhance the child’s motivation to solve the tasks and furthermore added a game like approach to the training. A third figure, the old Osarion, was introduced into the game. Osarion was represented by an icon in every task, and the children received a hint if they clicked on the icon or if they chose the wrong answer. The

game consisted of 120 tasks. The children trained in groups of three to four together with a teacher. Their classmates with hearing aids participated in the training as well. Therefore 27 children participated in the training, but as the children with HA did not participate in the baseline, pre-test and post-test sessions their data is not presented in the current study. Every training session consisted of 6 tasks. The teachers were instructed to play the game with the children 5 times a week if possible. The teachers received a manual with instructions on how to play the game before the training started. It was emphasized that the training game should not be played by the children alone. A list of step-by-step instructions was given to the teachers and they were told to work through these steps for every task in the game (see Table 2). This list was taken from the manual by Lenhard et al. (2011) and translated to Swedish. The steps were worked on as a group and the children explained their solutions to each other. The test leader was present during the first training session to ensure the training program worked and to answer questions. The rest of the training sessions took place without the test leader, but the teachers were able to contact the test leader via telephone or e-mail if they needed help.

Matrix Test. The Matrix test from the WNV test battery (Wechsler & Naglieri, 2007) was used to test the non-verbal analogical reasoning ability of the children. There is one demonstration trial, three practice trials and 41 test trials. The first six trials were bypassed as instructed by the manual (Wechsler & Naglieri, 2007). The child saw geometrical patterns as well as a question mark presented in a matrix. The size of the matrix differed between the trials. It was either a picture with a part missing or a 2 by 2, 2 x 3, 3 x 3 matrix. In addition to the matrix five response alternatives were presented. The child was asked which of the five alternatives fits best with the other stimuli. The test was terminated as soon as the child had given an incorrect answer to four out of five consecutive trials. The child received 1 point for every correct answer.

Animalogica. Animalogica (Stevenson et al., 2013) was used to assess the non-verbal analogical reasoning ability of the children. Animalogica is a computer-based test.

The children saw a 2x2 grid with one empty cell. In the other three cells, animals (one or two) of different colors (blue, yellow, red) and size (big and small), either facing left or right, were displayed. The position of the animals within the cells varied as well. They were either displayed in the top, middle, or bottom of the cell. In addition to the 2x2 grid, animals that the children could use to construct their answers were displayed on the screen. They were displayed in the right and left upper corner. There were always two kinds of animals that the children could choose from to construct their answers (for example: elephants and dogs). Both animals were presented in two sizes (big and small) and three different colors (blue, yellow, red). The children were able to drag and drop the animals into the empty cell. They could choose the number of animals, their color, their size, their placement in the cell (bottom, middle, top) and their viewing direction. The children were instructed to “solve the puzzle” by filling the empty cell in a way that matched with the three other cells. The test started with two practice trials in which the task was explained, and the child got feedback. If the child answered incorrectly his/her answer was automatically replaced by the correct one. There was no feedback indicating why this answer was correct. After the practice trials, 24 test trials followed. The child received one point for every correct answer. If the child was not able to use the computer mouse properly, s/he could instruct the test leader to drag and drop the animal.

Verbal Analogies. The Verbal analogies subtest from the ITPA-3 test battery (Hammill, 2013) was used to test verbal analogical reasoning. For this test the child had to fill in the missing words for sentences like: “A dad is big, a baby is . . . ?”. The test consisted of two practice trials and 25 test trials. Synonyms or dialect versions of the correct word were counted as correct. For every correct word the child received one point. The test was terminated if the child gave the wrong answer to three consecutive trials.

Story Comprehension. A Swedish translation (Eldblom & Sandberg, 2011; Holck et al., 2009) of a story comprehension task developed by Bishop and Adams (1992) was used to evaluate the story comprehension ability of the children. Two stories were available in

Swedish (Eldblom & Sandberg, 2011). One consisted of six sentences, the other of seven sentences. The child listened to the story and was subsequently asked 14 question, seven inferential and seven literal questions.

Semantic Fluency. The category animal was chosen for the semantic fluency test (Benton & Hamsher, 1976). The child was instructed to name as many animals as possible within one minute.

Phonemic Fluency. The Swedish phonemes associated with the letters F, A and S were chosen for the phonemic fluency test (Benton & Hamsher, 1976). The child was instructed to name as many words starting with the phoneme F in one minute, then s/he was instructed to name as many words as possible starting with the phoneme A in one minute, next s/he was instructed to name as many words as possible starting with the phoneme S in one minute.

Procedure

The children were tested three times. The order in which the tests were administered was randomized for each test session. For the story comprehension task two versions were available and they were alternated for the three test session of each child. All children were tested by a speech and language pathologist or a speech and language pathology student in the last university term. The testing was conducted individually in a quiet room at the school. A microphone or/and amplifier was used if available in the test room. Otherwise the children listened to the auditory test material via the laptop loudspeakers. The test trials of each test were used to adapt the sound level to the needs of the child (ensuring the auditory test material was heard well). The test sessions were recorded.

Data analysis

To analyze whether training increased the analogical reasoning and language ability of the children, a baseline, pre-test, post-test design was used. The difference in performance between baseline and pre-test (timepoint 0 and 1) was compared to the difference in

performance between pre-test and post-test (timepoint 1 and 2). A visual analysis of the data has been used. The individual data for each child was plotted to be able to visually investigate how their performance on the outcome measures changed between baseline, pre-test, and post-test. This kind of analysis was used instead of statistical test due to the small sample size. The aim was to investigate if the children improved more on the outcome measures between pre-test and post-test compared to between baseline and pre-test. The data analysis was conducted using R (R Core Team, 2016), with the package tidyverse (Wickham et al., 2019). The figures and tables were created using the packages ggplot2 (Wickham, 2016), ggpubr (Kassambara, 2020), knitr (Xie, 2020) and kableExtra (Zhu, 2019). The paper was written using the package papaya (Aust & Barth, 2020).

Results

Near Transfer

In Table 3 the descriptive group data for the baseline, pre-test and post-test result of the Matrix task is shown. The individual data is displayed in Figure 1. In Table 4 the descriptive group data for the baseline, pre-test and post-test result of the Animalogica task is shown. The individual data is displayed in Figure 2. In Table 5 the descriptive group data for the baseline, pre-test and post-test result of the Animalogica task is shown. The individual data is displayed in Figure 3

As can be seen in Figure 1 the improvement of three children (pink, orange and purple) is steeper between pre-test and post-test compared to baseline and pre-test. For one child (blue) the improvement is steeper between baseline and pre-test compared to pre-test and post-test. Looking at Figure 2 reveals that only one of the three children with a steeper improvement between pre-test and post-test for the Matrix test showed the same pattern for Animalogica (pink). This child did exceptionally well for the post-test of Animalogica. As most other children perform very low it could be argued that the result is influenced by a floor effect and the task might have been too hard for the age group. This is also indicated by

the low group median for all test time-points (see Table 4). The individual results for the verbal analogies (Figure 3) show, that only one child with a possible training effect for the Matrix task does show the same pattern for the verbal analogies test (purple). The performance of one of the children (orange) declines between baseline and pre-test and improves again between pre-test and post-test. This is likely an unreliable result as a decline in verbal analogical reasoning ability is unexpected. Three children show a steeper improvement between baseline and pre-test compared to pre-test and post-test (pink, green and turquoise). This might be due to the longer time period between baseline and pre-test compared to between pre-test and post-test.

No child showed a steeper improvement between pre-test and post-test compared to between baseline and pre-test for any of the near transfer measures.

Far Transfer

In Table 6 the descriptive group data for the baseline, pre-test and post-test result of the story comprehension task is shown. The individual data is displayed in Figure 4. In Table 7 the descriptive group data for the baseline, pre-test and post-test result of the semantic fluency task is shown. The individual data is displayed in Figure 5. In Table 8 the descriptive group data for the baseline, pre-test and post-test result of the phonemic fluency task is shown. The individual data is displayed in Figure 6.

The performance of two children declines between baseline and pre-test (pink and yellow) for the story comprehension task (see Figure 4). In addition, the performance of one child increases between baseline and pre-test and decreases between pre-test and post-test. This might be explained by the use of different stories for the baseline and pre-test. It might be that the two stories used did not have the same difficulty level. If this was the case, the results from the story comprehension task might be unreliable. No child showed a steeper improvement between pre-test and post-test compared to baseline and pre-test for this task.

The same was the case for the semantic fluency task (see Figure 5). For the semantic fluency task the performance of one child (orange) declines between baseline and pre-test. For the phonemic fluency task the performance of one child (turquoise) declines between baseline and pre-test (see Figure 6). The improvement between pre-test and post-test is steeper compared to the improvement between baseline and pre-test for only one child (blue).

No child improved more between pre-test and post-test compared to baseline and pre-test on all three far-transfer measures. In addition, those children showing a possible training effect on the near-transfer measures (pink, orange and purple) did not show the same pattern for the far-transfer measures.

Discussion

The aim of this study was to evaluate if a larger scale study of the analogical reasoning training developed by Lenhard et al. (2011) with children with CI would be useful. In this pilot study we evaluated whether the analogical reasoning ability of children with CI can be improved by means of the computerized cognitive training by Lenhard et al. (2011) and if effects transfer to language ability. The visual investigation of the data does not suggest near-transfer effects of the training to analogical reasoning performance. No child improved more between pre-test and post-test compared to between baseline and pre-test for all three analogical reasoning measures. This speaks against a general effect of the training on analogical reasoning ability. In addition, none of the children showing possible training effects for at least one of the near-transfer measures showed the same pattern for any of the far-transfer measures. Therefore, there is no indication for any far-transfer of analogical reasoning improvement to language ability.

The visual investigation of the individual results for the near-transfer (analogical reasoning) measures does not indicate a general training effect for the group of children tested in the current study. It could be argued that while the training might not be effective

for every child, some might still benefit. Although no child improved on all three analogical reasoning measures more between pre-test and post-test compared to baseline and pre-test, one child showed a larger improvement between pre-test and post-test compared to baseline and pre-test for the two non-verbal analogical reasoning measures. It could be argued that a verbal analogical reasoning task does not measure near transfer as analogical reasoning is tested in a different domain compared to the one in the training. The analogical reasoning training by Lenhard et al. (2011) trains non-verbal analogical reasoning ability. It might be the case that the two other children showing a possible training effect on the matrix task did not show the same for the Animalogica task due to a floor effect. The group median for this test was low and the task was maybe too difficult for the tested group. One of the children showing a possible training effect for the Matrix task did show the same pattern for the verbal analogies test. This indicates that this child improved his/her analogical reasoning ability during the training and that this effect might have even transferred to a different domain (verbal). However, it seems like only a limited number of children improved their analogical reasoning ability due to the training. In further studies training sessions should be recorded to be able to analyze if those children that have been more active during the sessions improve more. In addition, further investigation is needed to determine which variables might contribute to the effectiveness of an analogical reasoning training.

The results from the current study do not provide any evidence for a far transfer of the training by Lenhard et al. (2011) to language ability. None of the children who showed a possible training effect on the near-transfer measures, showed the same for any of the far transfer measures. However, far transfer would be expected to be associated with the near transfer of the training. The more the trained ability improves, the more improvement would be expected on tasks depending on those abilities. It could be argued that the age of the tested children was too high to expect effects of an improvement of analogical reasoning on language ability. It has been suggested that how language is acquired differs with age (Hernandez & Li, 2007). It might be that analogical reasoning is more important for the

early stages of language acquisition. This could be a reason why Marx et al. (2010) and Marx (2006) found effects of analogical reasoning training on language ability and we did not. Both Marx et al. (2010) and Marx (2006) tested kindergarten children who are younger than the children tested in the current study. This is, however, speculative and more research is needed to evaluate if analogical reasoning is only important for language acquisition up to a specific age.

Limitations of the study

The results presented in the current study are based on a small sample and should be seen as pilot results. However, the visual investigation of the data does not suggest that training effects would be expected with larger samples. As no child improved more on all analogical reasoning measures during the training period and only one child improved on both non-verbal analogical reasoning measures during the training period it is unlikely that the training leads to any general effects on analogical reasoning ability. A further limitation of the study is the differences in the time period between baseline and pre-test and pre-test and post-test. Due to practical considerations the time period between the baseline testing and the pre-test was six months, while the time period between pre-test and post-test was around 2 months. It could be argued that a shorter time between the test sessions might lead to a larger test re-test effect and thereby to an overestimation of the training effect. However, in this case a smaller improvement between baseline and pre-test compared to the improvement between pre-test and post-test would have been expected. Such a pattern of results was not found in the current study.

Conclusion

The results of this pilot study provide no evidence that the training by Lenhard et al. (2011) has large effects on analogical reasoning or language ability of children with CI. Only few children show a larger improvement in some of the outcome measures after conducting the training compared to between baseline and pre-test. It might be that those

334 were the children most active during the training sessions. In further studies training
335 sessions should be recorded to be able to evaluate the influence of the child's engagement on
336 the effects of the training. In addition, more research is needed to evaluate the influence of
337 cognitive abilities on language acquisition for different age groups. It might be the case that
338 only the language acquisition of very young children benefits from an improvement of
339 analogical reasoning ability.

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Table 1

Individual data of the participants of this study. The data were obtained via a questionnaire filled in by the parents.

Participant	Age	Gender	Age at Implantation	unilateral/bilateral	Communication Mode
35	83.00	f	36	bilateral	oral
36	97.00	f	24	bilateral	oral (10% sign)
37	95.00	m	24	bilateral	oral (10% sign)
38	98.50	m	60	unilateral	only oral
39	91.00	m	36	bilateral	only oral
40	84.00	f	12	bilateral	oral (sign as support)
41	79.00	f	66	unilateral	oral (10% sign)

Note. Age and age at implantation in months

Table 2

List of the steps the teachers were instructed to work through with the children for each task in the training.

Steps to solve the tasks
<i>Block tasks (Introductory tasks)</i>
1 What do you see? Talk about the properties of the items and what problem you have to solve.
2 How should you solve the task? Try to find and motivate a solution
3 Compare the properties and relationships of the items in the task.
4 If your solution was not correct go back to step 2. If the children did find an alternative solution explain to them that their solution is not wrong but that there is another solution. Go back to step 2 to find the other solution.
<i>Picture and Symbol tasks</i>
1 Do all steps you did before for the Block tasks, but before starting the next task:
2 Try to describe the task: Which terms could you use to describe the task? What is a good name or category for the task?
3 Compare the task: What is similar, what is different to previous tasks?
4 Describe your solution strategy: How did you find the solution? How did you control if your solution is correct? Try to talk about this with everyday words.
5 Formulate rules: Summarize solution strategies for this kind of task. Can you solve all tasks from this category the same way? What do you think?

Table 3

Descriptive group data for the Matrix test.

	n	median	min	max	IQR
baseline	7	9	2	12	5.00
pre-test	7	11	6	13	3.50
post-test	7	12	9	21	3.00

Table 4

Descriptive group data for the Animalogica test.

	n	median	min	max	IQR
baseline	7	0.50	0	3	1.00
pre-test	7	2.00	1	3	1.00
post-test	7	2.00	0	14	2.00

Table 5

Descriptive group data for the verbal analogies test.

	n	median	min	max	IQR
baseline	7	6.50	2.00	9.00	3.00
pre-test	7	7.00	1.00	19.00	10.50
post-test	7	11.00	7.00	18.50	9.50

Table 6

Descriptive group data for the story comprehension test.

	n	median	min	max	IQR
baseline	7	9	4	14	6.50
pre-test	7	11	9	13	1.50
post-test	7	13	8	14	2.50

Table 7

Descriptive group data for the semantic fluency test.

	n	median	min	max	IQR
baseline	7	8	4	14	3.50
pre-test	7	8	5	16	4.00
post-test	7	10	7	14	4.00

Table 8

Descriptive group data for the phonemic fluency test.

	n	median	min	max	IQR
baseline	7	4	2	15	5.00
pre-test	7	11	3	19	6.00
post-test	7	11	3	22	9.50

Figure 1. Matrix Reasoning: Individual data for the baseline, pre-test and post-test. The training was implemented between pre-test and post-test.

Figure 2. Animalogica: Individual data for the baseline, pre-test and post-test. The training was implemented between pre-test and post-test.

Figure 3. Verbal Analogies: Individual data for the baseline, pre-test and post-test. The training was implemented between pre-test and post-test.

Figure 4. Story Comprehension: Individual data for the baseline, pre-test and post-test. The training was implemented between pre-test and post-test.

Figure 5. Semantic Fluency: Individual data for the baseline, pre-test and post-test. The training was implemented between pre-test and post-test.

Figure 6. Phonemic Fluency: Individual data for the baseline, pre-test and post-test. The training was implemented between pre-test and post-test.