Do Bilinguals have More Cognitive Flexibility than Monolinguals?

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Abstract

The purpose of the present study was to compare between bilingual and monolingual university students to examine if there was any difference regarding two aspects of cognitive flexibility: the switch cost and perseverative errors. It was hypothesized that bilinguals should have significantly reduced switch cost and perseverative errors than monolinguals. These aspects were tested by conducting two experiments involving task switch processing: the Alternating Runs Task Switch Paradigm and Wisconsin Card Sorting Task. The convenient sample consisted of 64 bilingual and monolingual university students. The test results were analyzed through multiple independent T-tests. The results showed non-significant differences in the switch cost and perseverative errors between bilingual and monolingual university students. These results were discussed with previous research in mind and confirmed the inconsistency within the literature regarding cognitive differences between bilingual and monolingual young adults.

Keywords: Bilingualism, Monolingualism, Cognitive flexibility, Task switch, Switch cost, Perseverative errors, Alternating Runs Task Switch Paradigm, Wisconsin Card Sorting Task.
Sammanfattning


Do Bilinguals have More Cognitive Flexibility than Monolinguals?

An ordinary working day mostly include a broad span of events that demand a cognitive flexible behavior. Imagine a researcher trying to write an article. Suddenly a co-worker knocks at the door and asks about a detail mentioned at the conference last week. The researcher searches among his notes and recalls the detail. The researcher returns to focus on his article for one hour when he needs to stop because he has a meeting with his co-workers. He prepares a presentation and collects his material. When he is walking through the corridor towards the conference room, a poster about a famous professor in neurobiology holding a lecture suddenly catches his eyes. He thinks for a while and decides to sign up for the lecture. At last he enters the meeting room, greets his co-workers and introduces the meeting. Through this session, cognitive shifting behavior is striking. Writing an article, listening to a co-worker, scanning through material, recalling notes, collecting things, navigating, making decisions and socializing, all require the researcher to shift attention from one task to another. Being able to constantly shift the attention from one task to another and not be overwhelmed by distracting stimuli, is important for the researcher to complete his work successfully. To succeed in working life as well as everyday life, the ability to shift attention from one activity to another is crucial in modern society (Monsell, 2003).

According to Diamond (2013), the concept of cognitive flexibility is associated with executive functions. Executive functions is an umbrella term for a set of cognitive abilities which are essential for people to succeed in a goal-directed behavior, for example staying focused on an important task to be able to finish a work-task in time. Executive functions includes three interrelated abilities: inhibition, working memory and cognitive flexibility. Inhibition is the ability to control the attention and exclude unimportant stimuli that distract you from accomplishing a goal, for example not buying candy when you are trying to lose weight. Working memory is active when you are holding ongoing stimuli in memory and at the same time manipulating them, for example when you are trying to hold information on a computer screen in memory at the same time.
as you're having a conversation with a co-worker. Cognitive flexibility is the skill to shift attention from one stimulus to another, for example writing a thesis and shifting focus to cook a meal. Cognitive flexibility is also associated with creativity and openness; the opposite concept is rigidity. A person who is cognitively flexible can look for new ways to solve a problem and easily understand alternative solutions (Diamond, 2013). The present study will focus on the cognitive flexibility involved in executive functions.

Previous research has claimed that a high level of cognitive flexibility is related to many successful aspects of life (Diamond, 2013). Bailey (2007) has found an association between cognitive flexibility and work satisfaction. In his study, cognitively flexible employees were more efficient in processing information, made more accurate decisions and tended to attribute their job situations in a more rational and open way than the more rigid employees. This resulted in better complex cognitive processing such as planning, problem solving and compromising at work. The flexible employee can self-monitor their behavior and continuously adapt to new situations (Bailey, 2007). Vitiello, Greenfield, Munis & George (2011) have furthermore linked enhanced cognitive flexibility to school success in children. They found that strong cognitive flexibility improved school readiness and learning abilities. When the children exhibited cognitive flexibility, they were more motivated to learn, displayed less behavioral problems and interacted better with their peers. Cognitive flexibility was overall linked with educational satisfaction (Vitiello, et.al. 2011).

Furthermore, Eakin, Minde, Hechtman, Ocht, Krane, Boufaard, Greenfield & Looper (2004) have linked poor cognitive flexibility to a dissatisfaction in marital life. They investigated spouses with ADHD (a condition that involve poor executive functions) and found that they had less marital adjustment than spouses without ADHD. The poor cognitive flexibility included inflexible communication problems and less ability to solve problems in cognitively flexible ways. Spouses with ADHD were more likely to divorce than spouses without ADHD (Eakin, et.al, 2004). Brown & Landgraf (2010) reviewed that people with improved cognitive flexibility overall reported higher
degree of life satisfaction than people with low cognitive flexibility. The individuals reported higher well-being, better every day function, more satisfying relationships and communication, and less boredom than other individuals (Brown & Landgraf, 2010). There is a good reason to believe that enhanced cognitive flexibility is beneficial for meeting the demands of society.

In the early stages of cognitive flexibility (or task switching) research, Jersild (1927; ref. in Monsell 2003) noticed a switch cost when he carried out experiments regarding switching tasks. One task switch method he used was to add certain numbers and then switch to subtract the numbers. The delayed time-interval during the switch was measured. Decades later, Rogers & Monsell (1995) developed the Alternating Runs Task Switch Paradigm as a standardized tool for measuring the switch cost. According to Monsell (2003), the switch cost is a tendency to slow down and make errors due to the confusion when a person needs to switch focus from one task-set to another. A task-set is defined as a mental procedure which is configured by a specific mental ability, such as naming or categorization. If a person is cognitively flexible the task switching should be performed smoothly and efficiently, without too many errors. However if a person becomes too confused by the task switching, delaying significantly and making many errors, it is considered to be a sign that an individual tends to be rigid. The tendency of these two cognitively flexible behaviors can be measured by the switch cost. The switch cost was therefore used as a tool for measuring cognitive flexibility in the present study (Monsell, 2003; Rogers & Monsell, 1995).

It is important to recognize the extraneous variables within the task switching. An individual does not only use cognitive flexibility when he or she is switching between different tasks. Aspects like executive- and inhibitory control is also a part of the process. These aspects are measured by mixed cost within the Alternating runs task switch paradigms (Monsell, 2003; Paap & Greenberg, 2013; Prior & MacWhinney, 2010; Wiseheart, Viswanathan & Bialystok, 2014). Since this study intended to focus on cognitive flexibility, no further analysis regarding the extraneous variables were performed in the study.
Language is associated with cognitive processing. The ongoing activities associated with languages, listening on a certain topic, articulating a thought and shifting attention from one topic to another, are mentally demanding when a person exercises a language. When a person speaks two languages it becomes more complicated and there is more cognitive processing involved (Cook & Basetti, 2011). Nowadays, the world has a large bilingual population (Bialystok, 2010). Grosjean (2000) claims that half of the world’s population speak two languages or more. A bilingual person is considered as someone that regularly make uses of two languages, whereas a monolingual is someone that regularly make uses of one language (Grosjean, 1982). To regularly make use of two languages is more cognitively demanding than to make use only of one language (Bialystok, 2010). Bilinguals are forced into a cognitive flexible behavior when they shift from one language to another. This shifting behavior has led to a hypothesis that bilinguals have their cognitive abilities shaped, which results in having a special mental advantage compare to monolinguals who doesn't experience of shifting languages (Bialystok, 2010). If this hypothesis is true, it would mean that being a bilingual is beneficial for confronting the demands of society.

The definition of bilingualism mentioned above (someone that regularly make uses of two languages) is simplified. To make a clear definition of the concept of bilingualism is difficult. Historically, the concept of bilingualism has been divided between maximalistic and minimalistic definitions of bilingualism. The maximalistic definitions of bilingualism are strict and claim that a bilingual is an individual which has a high proficiency of two languages. Bloomfeldt (1933; ref. in Basetti & Cook, 2011) for example has defined a bilingual as someone that regularly make use of two languages with a native-like competence. The minimalistic definitions however are more relativistic. Haugen (1953; ref. in Basetti & Cook, 2011) has for example defined that bilingualism starts at the point where a speaker is able to produce complete and meaningful utterances in other languages. There are however problems with these two views. The maximalistic definition emphasizes too high demands of linguistic competence for someone that regularly make use of two
languages. Grosjean (1998; ref in Basetti & Cook, 2011) has noted that the linguistic proficiency of two languages can vary between bilinguals and that the language proficiency make progress during the years within bilingual individuals. It is therefore difficult to claim a total native-like proficiency within a bilingual. According to Basetti & Cook (2011), the minimalistic is too relativistic and vague. The minimalistic definition, claim that a bilingual could be an individual with the smallest competence by utterance a few sentences in a foreign language just as well as someone that can speak two languages with a high proficiency. The minimalistic definition is therefore unsatisfactory and rarely capture a distinct bilingual population that regularly make use of two languages in Sweden (Basetti & Cook, 2011). Even if most Swedes are able to speak meaningful utterances in English, it doesn’t mean that they necessarily make use the english language in their everyday life. Therefore, it is difficult to make a distinction between bilingualism and monolingualism with the minimalistic definition. To be able to make a distinction of bilinguals and monolinguals in the present study, a definition within the maximalistic spectrum needs to be applied. In the scope of this study, bilinguals are therefore considered as someone that have a good and well-balanced (but not perfect) linguistic competence between his or her native language and his or her second language. To expand the distinction further, the native language is defined as the language which the individual speaks at home with their parents and the second language is defined as the language which the individual mainly speaks in society (Komri-Nouri, Moniri & Nilsson, 2003). Since the language spoken in society is Swedish, a native language is considered as any language which is not Swedish. In conclusion, the definition of bilingualism in this study was an individual that speaks a non-Swedish language at their home and Swedish in society. The definition of a monolingual person in this study was someone that speaks Swedish in their home and Swedish in society. The motivation of these definitions was to identify two distinct groups of bilinguals and monolinguals and that it would capture a shifting behavior between the bilinguals when they regularly make use of their native language at home and Swedish in society.
From an early stage regarding cognitive research of bilingualism, researchers have noticed an association between bilingualism and cognitive flexibility, such as Peal & Lambert's (1962) pioneer study on bilingualism and cognitive abilities. They concluded that bilinguals have a significant advantage in mental flexibility compared with monolinguals (Peal & Lambert, 1962). Another related topic is the correlation between bilingualism and executive control (Bialystok, 1999; Bialystok & Martin, 2004). Executive control is an attentional skill - the ability to monitor and solve problems when attending stimuli. However, executive control is also a skill which involves the practice of task switching (Rubinstein, Meyer & Evans, 2001). Costa, Hernandez & Galle’s (2008) have found that bilinguals had an enhanced executive control, which gave them an advantage in task switching. They measured the executive control by exposing the bilinguals and monolinguals to congruent and incongruent stimuli and letting them switch between these trials. They found a more enhanced ability to monitor attention, solve problems and maintain an alert state in bilinguals than in monolinguals, which gave bilinguals advantages in task-switching (Costa, et.al, 2008). Moreover Carlson & Meltzoff (2008) compared Spanish-English bilingual children and English monolingual children to investigate whether the bilingual group performed better than the monolingual group at the Dimensional Complex Card Sorting Task. They measured executive functions more broadly. They concluded that bilinguals exerted higher levels of executive control which gave them beneficial inhibitory control and working memory. Furthermore, this advantage would also affect task switching (Carlsson & Meltzoff, 2008). To conclude, several studies have identified an enhanced ability in executive control in bilinguals, which gave them a better opportunity to switch between different tasks.

What is the rationale for the bilingual benefits in executive controls and task switching? Meuter & Allport (1999) investigated switch cost from language switching. They found that the switch cost was smaller when participants switched from their dominant language to their weaker, but the participants received larger switch cost when they switched from their weaker language to
the dominant. Meuter & Allport (1999) claim that this finding can be perceived as a paradox for a bilingual advantage at a first glance. However, these findings are hypothesized to lead to a better inhibitory control model labeled by Green (1998), which stated that bilinguals use an attentional control system to actively inhibit distractions from their dominant language. This leads to a general enhanced inhibitory control which is beneficial in the context of switching task (Green, 1998; Meuter & Allport, 1999). Furthermore, Kroll & Bialystok (2013) suggested a joint activation system of languages. Joint activation means that the languages are constantly activated when bilinguals communicate with others and that bilinguals need to suppress the competing language to avoid interference (Kroll & Bialystok, 2013). Overall, the suppressing activity leads to a better inhibitory control. The basic explanation for the advantages of bilinguals seem to depend on their enhanced inhibitory control resulted from a joint activated language lexicon. This inhibitory control is furthermore used in task switching behavior.

More recently, researchers have begun to isolate cognitive flexibility to find evidence for bilingual advantage according to the theory of task switch configuration through Task Switch Paradigms. Prior & MacWhinney (2010) were the first researchers to conduct a study applying a Task Switch Paradigm to investigate if bilinguals have a reduced switch cost compared to monolinguals. Their study was motivated by extending the findings for bilingual advantages in executive control, looking beyond the inhibitory control mechanism and examined the particular shifting processing within bilinguals. They intended to isolate the switch cost between bilingual and monolingual college students. If bilinguals had a reduced switch cost, the authors claimed that it is a valid sign of better ability in cognitive flexibility. In line with the authors' predictions, the result showed a significant difference for the bilinguals in switch cost (Prior & MacWhinney, 2010).

However Prior & MacWhinney's (2010) findings have not consistently been confirmed. Wiseheart, Viswanathan & Bialystok (2014) examined switch cost between bilinguals and monolinguals by using another switch paradigm. They found no switch cost between the groups
(Wiseheart, et.al. 2014). Furthermore Paap & Greenberg (2013) used the same paradigm as Prior and MacWhinney (2010) and found no effect in switch cost between bilinguals and monolinguals, and concluded there is no difference between bilinguals and monolinguals in cognitive flexibility (Paap & Greenberg, 2013). It seems that the research regarding bilingualism and task switch is inconsistent and that further examination is needed to investigate if a bilingual advantage in task switch is substantial. This study therefore examined the switch cost between bilinguals and monolinguals.

There is another problem regarding bilingualism and cognitive advantages. According to Valian (2014), several studies which concluded a positive effect regarding bilingualism and executive controls have been conducted on children and older adults, but many studies regarding bilingualism and executive control in younger adults have not confirmed these findings. According to Santrock (2015) young adults are considered as individuals which have an age-span between 20-40 years old. Therefore, it seems that the research regarding a bilingual benefit in cognitive flexibility have not been substantially confirmed for all age groups. Further research on cognitive flexibility between bilingual and monolingual young adults is therefore needed. This study will examine bilingual and monolingual university students in young adulthood.

Another way to assess the cognitive flexibility within a person is to measure the tendency to get stuck in habituated patterns. If a person is cognitively flexible, it is reasonable that the task-switch goes smoothly and without significant difficulties. But if a person has problem in shifting tasks and repeatedly get stuck in previous activities, it could be indicated that the person is rigid. The rigidity can be assessed by the perseverative errors. The perseverative errors display the tendency to fail in shifting from one stimulus to another and getting stuck in the previous trials (Davis & Nolen-Hoeskema, 2000; Kortte, Horne & Windham, 2002). If the participant has an ongoing tendency to miss the shifting stimuli, a further inference regarding cognitive flexibility can be made. The perseverative errors can be measured by the Wisconsin Card Sorting Task. In
conclusion, the perseverative errors are considered as a valid aspect of cognitive flexibility and was therefore used in this study as a tool for analyzing cognitive flexibility.

There is one study investigating perseverative errors among bilinguals (Vega & Fernandez, 2010). Vega & Fernendez (2010) examined the correlation between bilingual language proficiency and the outcome on different executive functions tasks. The Wisconsin Card Sorting Task was the task that specifically measured cognitive flexibility. They found a significant positive correlation between bilingual language proficiency and cognitive flexibility. The higher competence the bilinguals exerted in their languages, the fewer perseverative errors they made (Vega & Fernandez, 2010). The conclusion in the study was that bilingual language competence correlated well with cognitive flexibility. However, further research is needed to explicitly examine the difference between bilinguals and monolinguals regarding perseverative errors.

The aim of the present study was to compare between bilingual and monolingual university students in task switching to see if there were any differences in two aspects of cognitive flexibility: the switch cost and perseverative errors. It was hypothesized that the bilingual group would have a significantly better performance in switch cost on response time and error rate compared to the monolingual group on the Alternating Runs Task Switch Paradigm. It was also hypothesized that the bilingual group would have a significantly reduced perseverative error rate compared to the monolingual group on the Wisconsin Card Sorting Task.

Method

Participants

The participants were selected through convenience sampling. Overall the sample consisted of 64 students selected at Örebro University. 62 of the students were between 20-36 years old (M = 23.09, SD = 3.15), which indicated that they were young adults. However two of the students were 19 years old and are considered as adolescents, which is defined as individuals with an age span between 13-19 (Santrock, 2015). Because of the close age till young adults, these two individuals
were included in the study. There were 32 (16 males and 16 females) participants in each of the bilingual and monolingual groups. The monolingual group had Swedish as their first language. The bilingual group had Swedish as their second language and their native language as their first language. The languages were as follows: Arabic (n = 18), Armenian (n = 3), Dari (n = 3), Kurdish (n = 3), Persian (n = 1), Albanian (n = 1), Assyrian (n = 1), Chaldean (n = 1) and Icelandic (n = 1). Generally, the bilingual group rated their Swedish (M = 1.26, SD = .52) better than their native language (M = 2.39, SD = .83), which indicated a good and well-balanced language competence in the bilingual group. All participants were currently studying at Örebro university or had a university degree. 35 students worked part-time in parallel with their education at the university, while 29 students only studied at the university. 34 of the participants were single, 20 had a partner and 10 were married or co-habiting. Four of the students (Monolinguals, n = 3, Bilinguals, n = 1, Males, = 1 and Women, = 3), reported that they were under investigation or diagnosed with a cognitive deficit (Dyslexia, n = 1, Dyscalculia, n = 1 and Color blindness n = 2), but since they had average results on the experiments they were not excluded from the study.

**Measurements**

**Self-report questionnaire.** The Self-report questionnaire was a self-constructed measurement. The aim for this questionnaire was to collect general information about the characteristics of the participants. The Self-report consisted of information of the participants' gender, age, educational level and any potential diagnoses (see appendix 1).

**Self-rated Proficiency.** The self-rated language proficiency was a self-constructed survey designed to assess the bilinguals' competences in their first and second languages. Overall, the self rated language proficiency consisted of eight items, which were divided into two parts. The first part consisted of four items (concerning listening, talking, reading and writing abilities) which measured the bilinguals' self-perceived competence regarding their native language. The native language was defined as the language the participants spoke at home with their parents. The second
part consisted of four items (concerning listening, talking, reading and writing abilities), which measured the bilingual's competences regarding their Swedish language. The rating scales ranged from 1-5: 1 = “Very well”, 2 = “Pretty well”, 3 = “Neither well or bad”, 4 = “Pretty bad”, 5 = “Very bad” (see appendix 2).

A factor analysis was conducted to examine the factor structure of the eight item self-rated language proficiency scale using a promax rotation. The result revealed two distinct factors with eigenvalues larger than 1. The two factors explained 58.97% of the overall variations in the measure. Four items loaded on the native language factor, which explained 40.25% of the overall variation. The other four items loaded on the second language factor, which explained 18.72% of the variation. The loadings for the native language items ranged between .54 and .93, whereas the loadings for the second language items varied between .63 and .87. Inter-item reliability for the native language sub scale was .76 and inter-item reliability for the second language sub scale was .83, which were higher than the conventional cutoff value of Cronbach alpha (.70). The factor analysis confirmed that the measurement loaded on two factors. The Cronbach alpha confirmed the inter-item reliability. The overall analysis confirmed that the Self-rated proficiency was a reliable measurement.

**Alternating Runs Task Switch Paradigm.** The Alternating Runs Task Switch Paradigm was developed by Rogers & Monsell (1995) as a measurement for the task-switch configuration through the switch cost. The Alternating Runs Task Switch Paradigm used in this study was downloaded through a website (www.psytoolkit.org). The Alternating Runs Task Switch Paradigm is characterized by a predictable procedure, which means that the participant knows when to switch stimulus. The stimuli appear within four different squares, two top squares and two bottom squares. The stimuli are combinations of letters and numbers. The two top squares are intended for the letter stimuli and the two bottom squares for the number stimuli. The letters consist of four consonants (G, K, M, R) and four vocals (A, E, O, U). The participant is expected to press B for consonants and N
The numbers consist of four odd numbers (3, 5, 7, 9) and four even numbers (2, 4, 6, 8). The participants are expected to press B for odd numbers and N for even numbers. The stimuli appear simultaneously within the squares, for example “7E”. Overall, the Alternating Runs Task Switch Paradigm consists of three task-sets. The first and second task-sets are defined as simple tasks, which only consist of non-switch trials. Non-switch trials are defined as repetitive trials which switch from either letters to letters or numbers to numbers (L-L-L-L or N-N-N-N). The first task-set consists of only letters (L-L-L-L). Overall, 40 letters were presented. The second task-set consists of only numbers (N-N-N-N). Overall, 40 numbers were presented. The third task-set consists of a mixed task, which consists of non-switch trials and switch trials. Switch trials are defined as stimuli that switch from either letter to number or from number to letter (L-N or N-L). Overall, 40 letters and numbers are presented within the mixed task. 20 trials are considered as non-switch trials, which change from either letters to letters or from numbers to numbers (L-L or N-N). Furthermore, 20 trials are considered as switch trials, which means that the trials are changing from either letter to number or from number to letter (L-N or N-L). According to the procedure, the stimuli switch around in a clockwise rotation, L-L-N-N-L-L-N-N. If the participant committed an incorrect trial, a sign on the computer screen appears with the word “ERROR”. The sign disappears after about 4 seconds and signals the proceeding of the experiment. The participant has a time-interval of 5000 milliseconds to respond to each stimulus. If the participant does not respond to the stimuli, he or she receives an incorrect trial.

**Switch cost.** To pinpoint the aspects of cognitive flexibility within the test, Rogers & Monsell (1995) claimed that the researcher needs to calculate the switch cost. The switch cost is defined as a delay in response time and an increased amount of errors in the context of task switch (Monsell, 2003). The switch cost can be assessed in two ways in the Alternating Runs Task Switch Paradigm.

The first kind of switch cost focuses on the non-switch trials within the simple tasks and
mixed task. By assessing the participants' selection of vocals or consonants on the non-switched trials for letters and odd or even numbers on the non-switched trials for numbers, a calculation of the first kind of switch cost is possible. This switch cost is calculated by subtracting the mean response time and error rates in percentage from the non-switched trials of the mixed task from mean response time or error rates in percentage from the non-switched trials of simple tasks.

The second kind of switch cost focuses only on the mixed task. This kind of switch cost is calculated by subtracting the mean response time and the number of error rates in percentage in the switch trials, from the mean response time and the number of error rates percentage in the non-switch trials of mixed task (Prior & McWhinney, 2010; Rogers & Monsell, 1995). By comparing the switch costs regarding response time and the error rates percentage between the bilingual and monolingual groups, a valid measure regarding cognitive flexibility can be analyzed.

**Wisconsin Card Sorting Task.** According to Crone, Ridderinkhof, Worm, Somsen, Van der Molen (2004), the Wisconsin Card Sorting Task is a more complex test than the Alternating Runs Task Switch Paradigm. The Wisconsin Card Sorting Task has therefore been criticized for measuring problem solving instead of cognitive flexibility. It has also been suggested to correlate with working memory and inhibition (Ozonoff & Strayer, 1997; Snitz, Curtis, Zald, Katsanis & Iacono, 1998). However, some researchers have considered the Wisconsin Card Sorting Task as a reliable tool for analyzing cognitive flexibility (Crone, et.al, 2004; Davis & Nolen-Hoeksema, 2000; Kortte, et.al. 2002; Tchanturia, Davis, Roberts, Harrison, Nakazato, Schmidt, Treasure & Morris, 2012). The construct validity as a test for measuring cognitive flexibility was explicitly assessed and confirmed by Miayake, Friedman, Emerson, Witzki & Howerter (2000). The Wisconsin Card Sorting Task used in this study was a computerized version and was downloaded through a website (www.psytoolkit.org).

The Wisconsin Card Sorting Task is designed with a total six task-sets with ten trials for each task-set. Overall, there were 60 trials in the test. The trials are displayed as cards with three
different themes: shape, number and color. The shape theme is displayed as triangles, stars, circles and plusses. The number theme is revealed by the number of shapes that are displayed on the card, for example two circles or three plusses. The number span on the cards vary between one to four. The color theme is revealed within the shapes and the colors are displayed as red, green, yellow and blue. The participant needs to match a stimulus card with one of four category cards on a computer screen. The correct trials were achieved if the participant managed to match the theme on the stimulus card with the accurate theme on the category card. The correct trials respond by a signal and a sign on the computer screen saying “CORRECT”. The incorrect trials respond by a voice saying “NO” and a sign on the computer screen saying “WRONG”. All themes appear simultaneously, which therefore requires the participant to choose one distinguished theme and exclude the others. The participant has 10 000 milliseconds to match the stimulus card with the category card. If the participant fails to match a card, he or she gets an incorrect trial.

Wisconsin Card Sorting Task has a predestined procedure, which determines the theme within each task-set. The procedure of the task-sets in the Wisconsin Card Sorting Task was: first task-set: Shapes (n = 10), second task-set: Numbers (n = 10), third task-set: Colors (n = 10), fourth task-set: Shapes (n = 10), fifth task-set: Numbers (n = 10), and eventually, sixth task-set: Colors (n = 10). The critical moments during the test are when task-sets switch from one theme to another, for example the task-set switching from shape to number or from number to color. If the participant fails to switch strategy after the first incorrect trial within the new task-set and repeatedly select previous trials (for example the participant failed to switch from shapes to numbers and repeatedly click on shapes instead of numbers), this is considered as a rigidity by the participant. This rigidity can be measured by the perseverative errors within the test.

**Perseverative errors.** The perseverative errors is considered as the valid measure of cognitive flexibility in the Wisconsin Card Sorting Task (Crone, et.al, 2004; Davis & Nolen-Hoesksema, 2000; Kortte, et.al. 2002; Tchanturia, et.al, 2012). The perseverative errors in the
Wisconsin Card Sorting Task is defined as the failure to switch category after receiving negative feedback from previous trial (Barcelo & Knight, 2002; Crone, et.al, 2004). To analyze the perseverative errors further, the percentage of perseverative errors needs to be computed (Kortte, et.al. 2002). It is important to exclude the first trial in task-set 2, 3, 4, 5 and 6 when computing the perseverative errors. The first trial within these task-sets is considered as a task-switch signal and not as perseverative tendency within the participant. Since the participant is unprepared for the task-switch it is reasonable to exclude this trial from the assessment. However, if the participant still selects a category card with a theme according to the previous task-set after the task-switch signal, it should be considered as a reliable perseverative errors (Barcelo & Knight, 2002; Crone, et.al, 2004). After the computation of the perseverative errors in percentage, a comparison between bilingual and monolingual groups is possible.

**Additional variables.** In additional, other variables that can be assessed in the Wisconsin Card Sorting Task are: total correct, response time and non-perservative errors. The total correct trials within the Wisconsin Card Sorting Task provide an overall analysis about the general performance on the test between bilinguals and monolinguals. The response time assesses the speed processing of participants in the Wisconsin Card Sorting Task. Non-perservative errors is defined as the errors when the participants select incorrect trials which are related to the different series than the previous one. Non-perservative errors correlates more with inhibition, working memory and monitoring than cognitive flexibility (Barceló & Knight, 2002; Tchanturia, et.al. 2012).

**Procedure**

Most of the participants were selected randomly at the Örebro University campus and asked to participate in the experiments. Some of the participants were contacted by phone or e-mail. The participants were taken to a discrete room with a computer. The participants were informed of the aim of the study and their opportunity to withdraw from the test any time they want. They were further informed about the confidentiality of the test and that their identity will be coded by a
number. After the introduction, the participants answered a questionnaire concerning their
demographical information and a questionnaire about their language proficiency.

Furthermore, the participants were instructed about the Alternating Runs Task Switch
Paradigm. The participants first read a written instruction on the computer screen about the test
procedure, followed by an oral instruction and a visual demonstration. The variety of instructions
secured that the participants were given substantial information regarding the test procedure so that
no confusion would occur during the test sessions. The participants had three preparation sessions
to get familiar with the test procedure. The first preparation session included three non-switch trials
(letters). The second preparation session included three non-switch trials (numbers). The third
preparation session included two switch trials and one non-switch trials (two letters and one
number). After the preparation sessions, the original test was conducted. When the test was
completed the output of the result for the three test conditions were saved in a separate excel file for
further analysis. The participant was then asked about his or her impressions about the test at the end.

Moreover, the participants were instructed about the Wisconsin card sorting task. They read
a written instruction about the test procedure on the computer screen, which was followed by an
oral instruction. The participants had one preparation session to get familiar with the test procedure,
which included three trials. After the preparation session, the original test was conducted. When the
test session was completed the result of the Wisconsin Card Sorting Task was saved in a separate
excel file for further analysis. As in the Alternating Run Task Switch Paradigm, the participants
were asked to give their own impressions regarding the test at the end.

Statistical Analyses

To compare the differences in the switch costs and the perseverative errors between
bilinguals and monolinguals, multiple independent T-tests were conducted. The independent T-tests
compared the switch costs in response time and error rate percentage between bilinguals and
monolinguals. Furthermore, the independent T-tests compared the perseverative errors between bilinguals and monolinguals. The T-tests were performed by the Statistical Package for the Social Sciences.

**Result**

It was hypothesized that bilingual university students would perform significantly better on the switch cost in response time and error rate compared to monolingual university students. The switch cost was analyzed in two ways. The first kind of switch cost focused on the difference between the simple tasks and the mixed tasks, while the second kind of switch cost focused on the difference between switch trials and non-switch trials in the mixed task.

The calculation of the simple tasks and mixed tasks was done in two steps. The first step encompassed subtracting the response time and the error rates from the letters in the mixed task from the letters in the simple tasks. The second step encompassed subtracting the response time and the error rates for the numbers in the mixed task from the numbers in the simple tasks. These results are shown in table 1.

Multiple independent T-tests were conducted to analyze the descriptive data in Table 1. The independent T-tests were conducted to assess whether bilinguals had a significantly reduced switch costs on the simple tasks and mixed task compared to monolinguals regarding to response time and error rate on the Alternating Runs Task Switch Paradigm. The result from the first independent T-test showed a non-significant difference in switch cost on response time between bilinguals and monolinguals on the simple task and mixed task with letters, $t(62) = -.498$, $p = .620$. Monolinguals had a non-significant reduced switch cost in response time compared to bilinguals. The result from the second independent T-test also showed a non-significant difference on the switch cost in the error rates between bilinguals and monolinguals on the simple task and the mixed task with letters, $t(62) = -1.171$, $p = .246$. Monolinguals had a non-significant reduced switch cost in error rates compared to bilinguals on the simple task with letters and the mixed task with the trials related to
Table 1. Calculation for switch cost between simple tasks and mixed tasks of letter and number trials. Mean and standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>BILINGUALS</th>
<th></th>
<th>MONOLINGUALS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Simple task (L)</td>
<td>Mixed task (L)</td>
<td>Switch cost (L)</td>
<td>Simple task (L)</td>
</tr>
<tr>
<td>RT in milliseconds</td>
<td>877.50 (222.42)</td>
<td>1414.71 (400.21)</td>
<td>537.21 (6.97)</td>
<td>854.11 (213.43)</td>
</tr>
<tr>
<td>% Correct</td>
<td>96.02 (5.11)</td>
<td>92.03 (7.31)</td>
<td>95.78 (4.98)</td>
<td>94.22 (9.74)</td>
</tr>
<tr>
<td>% Error</td>
<td>3.98 (5.11)</td>
<td>7.97 (7.31)</td>
<td>3.99 (9.18)</td>
<td>4.22 (4.98)</td>
</tr>
</tbody>
</table>

|                  | Simple task (N) | Mixed task (N) | Switch cost (N) | Simple task (N) | Mixed task (N) | Switch cost (N) |
| RT in milliseconds | 831.86 (155.13) | 1299.28 (328.91) | 467.42 (286.33) | 804.24 (158.31) | 1232.99 (321.08) | 428.75 (263.63) |
| % Correct        | 96.17 (2.98) | 93.91 (9.79) | 96.48 (2.83) | 93.44 (8.20) |
| % Error          | 3.83 (2.98) | 6.09 (9.79) | 2.26 (9.89) | 3.52 (2.83) | 6.56 (8.20) | 3.04 (6.97) |
letters. The result from the third independent T-test showed a non-significant reduced switch cost on response time, between bilinguals and monolinguals on the simple task and mixed task with numbers, t (62) = -.562, p = .576. Monolinguals had a non-significant reduced switch cost in response time compared to bilinguals. The result from the fourth independent T-test also showed a non-significant difference on the switch cost in error rates between bilinguals and monolinguals on the simple tasks the mixed task with numbers, t (62) = -.073, p = .942. Bilinguals had a non-significant reduced switch cost in error rates compared to monolinguals. In conclusion, the hypothesis that bilinguals would have a significant reduced switch cost was not supported by the independent T-tests.

The switch cost was also calculated by subtracting the switch trials from the non-switch trials in the mixed task. The switch trials were separated from the non-switch trials, and the error rate percentages and the means response time were then calculated in these trials. The switch cost for response time and error rates was then calculated by subtracting the switch trials from the non-switched trials. These results are shown in table 2.

Table 2. Calculation for switch cost between the switch trials and non-switch trials within the mixed task. Mean and standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>Switch trials</th>
<th>Non-switch trials</th>
<th>Switch cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bilinguals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>1606.48 (474.28)</td>
<td>1107.52 (286.16)</td>
<td>498.96 (368.60)</td>
</tr>
<tr>
<td>%Correct</td>
<td>90.94 (9.02)</td>
<td>94.53 (10.42)</td>
<td></td>
</tr>
<tr>
<td>%Error</td>
<td>9.06 (9.02)</td>
<td>5.47 (10.42)</td>
<td>3.59 (8.64)</td>
</tr>
<tr>
<td><strong>Monolinguals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>1549.63 (451.60)</td>
<td>1032.96 (253.16)</td>
<td>516.67 (376.85)</td>
</tr>
</tbody>
</table>
Several independent T-tests were conducted to compare the response time and error rates of the switch costs in the mixed task of Alternating Runs Task Switch Paradigm, between bilinguals and monolinguals. The result of the first independent T-test showed a non-significant difference regarding the response time of switch cost between bilingual and monolingual university students, \( t(62) = .180, p = .858 \). The bilingual group had a non-significant reduced switch cost in response time compared to the monolingual group. Furthermore, the second independent T-test was conducted to compare the error rates of the switch cost between bilingual and monolingual university students. The result of the showed a non-significant difference between bilingual and monolingual university students, \( t(62) = 1.170, p = .247 \). The bilingual group performed at non-significant lower error rate compared to the monolingual group. In conclusion, the result of the independent T-test did not support the hypothesis that bilinguals would have a significantly reduced switch cost compared to monolinguals in the Alternating Runs Task Switch Paradigm of the switch cost.

It was further hypothesized that bilinguals would have significantly reduced perseverative errors compared to monolinguals on the Wisconsin Card Sorting Task. Several independent T-tests were conducted to compare between bilingual and monolingual university students in their total correct trials, total response time, the perseverative errors and non-perseverative errors. The result from the first independent T-test showed a non-significant difference regarding the total correct trials \( t(62) = 1.049, p = .298 \). The monolinguals had a higher total correct compared to bilinguals. Furthermore, the result of the second independent t-test showed a non-significant difference regarding the response time, \( t(62) = -1.32, p = .191 \). The monolingual group performed Wisconsin Card Sorting Task at a slower speed compared to the bilingual group. Moreover, the result of the
third independent T-test showed a non-significant difference regarding the perseverative errors, \(t(62) = -0.785, p = .436\). The monolingual group committed less perseverative errors compared to the bilingual group. The result of the fourth independent T-test also showed a non-significant difference regarding non-perseverative errors, \(t(62) = -1.123, p = .266\). Monolinguals committed non-significantly less non-perseverative errors compared to bilinguals. In conclusion, the result of the independent T-test did not support the hypothesis that bilingual university students would perform significantly better than the monolingual university students in regards of perseverative errors within the Wisconsin Card Sorting Task. These results are shown in Table 3.

**Table 3. Means and standard deviations for total correct, response time, perseverative errors and non-perseverative errors.**

<table>
<thead>
<tr>
<th></th>
<th>Correct %</th>
<th>RT</th>
<th>Perseverative errors</th>
<th>Non-perseverative errors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bilinguals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>75.83</td>
<td>4763.08</td>
<td>11.09</td>
<td>5.47</td>
</tr>
<tr>
<td>SD</td>
<td>11.60</td>
<td>1569.33</td>
<td>9.07</td>
<td>5.01</td>
</tr>
<tr>
<td><strong>Monolinguals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>78.54</td>
<td>4319.33</td>
<td>9.48</td>
<td>4.27</td>
</tr>
<tr>
<td>SD</td>
<td>8.88</td>
<td>1072.53</td>
<td>7.30</td>
<td>3.36</td>
</tr>
</tbody>
</table>

**Discussion**

Previous research has suggested that bilingual children and older adults perform better in tasks that involve shifting from one activity to another (Bialystok, 2010). However, a bilingual advantage in task switch for young adults has been inconsistent within the research literature (Valian, 2014). The present study found that bilinguals and monolinguals did not differ in the efficiency or accuracy when a task-switch is required. Furthermore, the bilinguals and monolinguals do not display any differences in rigidity when a new task-set is introduced. In conclusion, the
findings in the present study suggest that there are no bilingual advantage regarding cognitive flexibility.

This study has not confirmed the claim within the psycholinguistic literature that bilinguals have certain advantages in cognitive flexibility compared to monolinguals (Bialystok, 2010). Instead, it has confirmed the inconsistency in this research field, suggesting no difference between bilinguals and monolinguals young adults in cognitive flexibility (Valian, 2014). The present study replicates the examinations conducted by Prior & MacWhinney (2010), Paap & Greenberg (2013) and Wisehart, et.al. (2014) regarding the performance between bilingual and monolingual young adults in Task Switch Paradigms. The findings in this study confirm Wisehart, et.al. (2014) and Paap & Greenberg's (2013) conclusions, that there is no difference in the switch cost between bilinguals and monolinguals. However, it fails to support Prior & MacWhinney's (2010) claim of a significantly reduced switch cost between bilingual and monolingual university students. The present examination suggests no difference in the switch cost between bilingual and monolingual university students, at least not in the Alternating Runs Task Switch Paradigm.

Additionally, the Wisconsin Card Sorting Task is applied in the present study. The literature regarding Wisconsin Card Sorting Task as a measurement for comparing bilingual and monolingual university students is lacking. Vega & Fernandez (2010) has used the Wisconsin Card Sorting Task to compare bilingual children with each other. However, their focus is about how bilingual language proficiency affects the perseveration errors in the Wisconsin Card Sorting Task. There is no study that explicitly compare bilinguals and monolingual young adults through the Wisconsin Card Sorting Task against each other. Thus, the comparison between bilingual and monolingual university students by the Wisconsin Card Sorting Task is in this respect a unique study in the field.

The non-difference between bilinguals and monolinguals in tasks measuring cognitive flexibility seems to be more distinct when the individuals are young adults. A question is why young adults tend to be equivalent in these cognitive tasks, while children are reported to display a
substantial difference (Bialystok, 2010, Valian, 2014). One explanation can be that children spend more time at home with their family during the early years of their life, while young adults are more active in society. The bilingual children are therefore, to a greater extent, required to shift between their native language when they speak to their parents, and their second language which is spoken in society. The higher levels of shifting behavior that bilingual children are exposed to at home can positively affect their cognitive flexibility during bilingual childhood. However, when the bilinguals come into young adulthood they become more active in society and spend more time with their friends and at work; they use their second language more and have less need for shifting to their first language. These tendencies can attenuate the shifting behavior within bilingual young adults and make them more similar to monolinguals with regards to cognitive flexibility. Kormi-Nouri, Moradi, Moradi, Akbari-Zardkhaneh & Zahedian's, (2012) research regarding how a bilingual language proficiency can affect the cognitive advantage, support this explanation. Kormi-Nouri, et.al (2012) noted that when bilingual children moved from grade 1 to 5, their second language was improved at the cost of their first language being impoverished. This gradual worsening of bilingual proficiency was suggested to affect the bilingual cognitive advantage negatively (Kormi-Nouri, et.al. 2012).

Another explanation, suggested by Valian (2014), is that young adults (both bilinguals and monolinguals) are at their peak of exercising cognitively demanding activities as a whole, not only speaking languages. Young adults are more involved in cognitively advanced activities like planning a summer camp, shifting between extra work and studies and in the creativity of writing a novel. It seems reasonable to conclude that these cognitively demanding activities among bilingual and monolingual young adults should level out the differences in their cognitive flexibility (Valian, 2014).

The present study focuses explicitly on cognitive flexibility by analyzing bilingual and monolingual university students' performance on two switch tasks. However, the question is
whether bilinguals have other cognitive abilities that can enhance their performance in cognitive tasks. As noted in the introduction within the present study, two theories suggested in bilingual research are the inhibitory control model (Green, 1998) and the joint activation system (Kroll & Bialystok, 2013). These theories claim that bilinguals exercise a continuous inhibitory control processing by suppressing their dominant language of interference when they be exposed of shifting language. The inhibitory control within bilinguals claims to enhance bilinguals' executive control and monitoring, because of suppressing interferences. In the present study the executive- and inhibitory control are targeted by analyzing the non-perservative errors within the Wisconsin Card Sorting Task (Barceló & Knight, 2002; Tchanturia, et.al, 2012). The results do not show any difference between bilingual and monolingual university students for their non-perservative errors. However, further research needs to be performed to pinpoint the inhibitory control to a higher extent than cognitive flexibility.

The present study has some limitations. Two participants were 19 years old and could not be considered as young adults according to definition. Furthermore, there was a risk of sampling bias by contacting selected participants by e-mail or phone. To avoid this sampling bias, it would had been better to be consistent in randomly selecting participants on campus. To detect a significant difference among bilingual and monolingual university students, it would have been necessary to increase the number of participants in the present study. In the present study, the number of participants was limited to 64. The statistical analysis would have been clearer if the number of participants were increased. Furthermore, another limitation laid within the construct of the self-report questionnaire. A factor that would have been important to examine was the level of tiredness the participant felt when he or she performed the tests. If a participant was exhausted during the test session, it could have negatively affected the performance of the participant. Retrospectively, it would had been wise to include an additional survey that examined the levels of tiredness the participants experienced when performing each test. Another way to avoid the effects of tiredness
was to counterbalance the experimental procedure. By regularly shifting the order of the Alternating runs task switch paradigm and the Wisconsin card sorting task systematic effects of tiredness could have been balanced up. Moreover, the present study also has a limitation within the examination of the Alternating Runs Task Switch Paradigm. The analysis of the Alternating Runs Task Switch Paradigm solely focused on the switch cost for measuring cognitive flexibility. The extraneous factors that can have affected the performance, like inhibition and executive control, were not controlled for. By analyzing the mixed cost, a more valid examination regarding the executive- and inhibitory control within Alternating Runs Task Switch Paradigm can be done. There are also weaknesses regarding the control for the self-rated language proficiency in the study among the supposed monolingual students. Even if the Swedish students were identified as monolinguals within the study since they speak their native Swedish language both in their home and society, the self-rated language proficiency did not control the competence for a possible second language apart from Swedish (for example English). If there were supposed monolinguals in the study who regularly speak English in their everyday life, it could have influenced their shifting behavior and made them more cognitively flexible. By excluding the supposed monolinguals from rating the competence of a possible second language within the self-rated language proficiency, important information regarding the language proficiency within the supposed monolingual group was missing. A related topic is the definition of bilingualism itself. There is a question if it is possible to suppose that a bilingual shifts more between two languages just because he or she speaks the native language in the home and a second language in the society. Some of the supposed monolinguals could perhaps attend an international study program at the university and regularly shift between Swedish and English in their everyday life. By defining the concept of bilingualism more straightforward in how often the individuals shift between their native and second language, a more valid group of bilinguals could have been selected according to the assumptions in this study.

The present study also shows some strengths. The participants were examined by two
recognized task-switch designs within the research field connected with cognitive flexibility: the Alternating Runs Task Switch Paradigm and the Wisconsin Card Sorting Task. Furthermore, the factors in the present study (the switch cost and perseverative errors) have a long tradition within the cognitive psychological research field as a construct for measuring cognitive flexibility. Moreover, the present study also controlled for extraneous variables within the Wisconsin Card Sorting Task by the examination of the non-perseverative errors. By pinpointing the non-perseverative errors other factors like inhibition and monitoring could have been analyzed. There is also a well-balanced scope of participants in the present study, since the bilingual and monolingual groups consisted of an equivalent number of participants. There was also an equal number of males and females in the study.

To be a bilingual did not seem to affect the cognitive flexibility compared to monolinguals, at least not in young adulthood. The certain advantages that are gained from an ability to shift from one activity to another seem to be equal among bilingual and monolingual university students. This conclusion dismisses the claim that shifting language is a substantial factor for developing cognitive abilities. However, this finding does not exclude the reported observations of a bilingual advantage in cognitive flexibility among children and old adults. To expand the scope of the examination regarding a bilingual cognitive advantage, it is necessary to examine the inhibitory control model and joint activation system more closely and ask to what extent inhibition and executive control affect bilingual cognitively abilities. In the scope of the present study, this expansion is not possible. It would also be interesting to examine the cognitive activities among young adult university students more broadly. If monolingual and bilingual university students who are young adults are involved in an equal amount of cognitive demanding activities, it seems reasonable to hypothesize that these activities can overcome the cognitive affection caused by language and make bilinguals and monolinguals more cognitively equivalent. By surveying the cognitive activities among young adult university students more closely, a mapping regarding what type of cognitive activities might
affect cognitive abilities can be conducted. In conclusion, the present study has examined the differences in cognitive flexibility between bilingual and monolingual university students. The findings do not support the view of a bilingual cognitive advantage over monolinguals. Further research is needed to shed a light on the potential differences between the cognitive abilities of young adults, old adults and children when it comes to language and cognitive flexibility.

References


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BILINGUALISM AND COGNITIVE FLEXIBILITY

doi.org/10.1017/S1366728910000192


doi:10.1207/S15324826AN0902_5


doi:10.1016/S1364-6613(03)00028-7


Appendix 1

**Personupplysningar**

1: Kön:
A: Man  B: Kvinna  C: Annat

2: Ålder:

3: Arbetar du i någon form: extraarbete, halvtid eller heltid?
A: Ja  B: Nej

4: Civilstånd:
A: Gift/Sambo  B: Partner  C: Singel

5: Vilken utbildning avslutade du senast?
A: Grundskola  B: Gymnasieutbildning  C: Universitets/Högskoleexamen

6: Studerar du för tillfället på universitet/högskola eller annan högre utbildning?
A: Ja  B: Nej

7: Är du enspråkig eller tvåspråkig? ("tvåspråkig" syftar på att du talar ditt modersmål t ex arabiska med dina föräldrar i hemmet och svenska i skolan och samhället)
A: Tvåspråkig  B: Enspråkig

8: Vilket språk talar du mest hemma med dina föräldrar?

9: Vilket land är du född i?
A: Sverige  B: Annat: _________________________

Om du svarade ”Annat”: Hur gammal var du när du blev bosatt i Sverige?

10: Är du under utredning eller har diagnosticerats med en diagnos som kan påverka din förmåga vid kognitiva tester? T ex ADHD eller Dyslexi
A: Ja  B: Nej

**Information nedan fylls i av Testledare**

Tidpunkt för testning:
Löpnummer:
Appendix 2

*Självuppskattning av språkfärdigheter*

<table>
<thead>
<tr>
<th>Hur bra upplever du att du behärskar ditt MODERSMÅL angående…</th>
<th>Mycket bra</th>
<th>Bra</th>
<th>Varken bra eller dåligt</th>
<th>Dåligt</th>
<th>Mycket dåligt</th>
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<tbody>
<tr>
<td>att förstå (lyssna)?</td>
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<tr>
<td>att tala?</td>
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<td>att läsa?</td>
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<th>Varken bra eller dåligt</th>
<th>Dåligt</th>
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