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Non-word reading test vs anaesthesia. How do anaesthetised patients decode the contents without referring to the meaning?

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Abstract

Background: The aim of this study was to examine the phonological functioning (reading speed and accuracy) of hospital patients under general anaesthesia administered during colonoscopy.

Methods: In this study the 'Łatysz' non-word reading test was used to measure the impact of selected anaesthetics on the phonological aspect of language processing (defined as decoding without referring to the meaning) in a group of 22 anaesthetised patients compared to 23 non-anaesthetised patients from university clinics.

Results: Compared to the preoperative performance, a decrease in reading accuracy and reading speed was observed only in the Anaesthesia Group — AG (in the subjects aged ≥ 35 years) 1.5 h after the administration of anaesthetics. Postoperatively, the AG were significantly slower and less accurate than the Control Group — CG — after 1.5 h. After 3 h, the AG had regained their baseline values both in reading accuracy and reading speed. During the last assessment session, the AG pronounced 82% of the words correctly, while the CG pronounced 74% correctly. Moreover, subjects aged ≥ 35 years performed worse than younger subjects in their reading accuracy and speed.

Conclusions: The patients who underwent colonoscopy under general anaesthesia manifested impaired phonological functioning shortly after the procedure, both in the speed and accuracy of reading non-words. However, the accuracy problems subsided relatively quickly.

Key words: anaesthesia, anaesthetics, intravenous, propofol, midazolam, reading impairment, phonology

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Modern anaesthetics administration, which affects cognitive processing and nervous system activity, provides an oportunity to control human consciousness in a reversible manner. Most surgical procedures are performed under general anaesthesia, which provides sleep, pain alleviation, and reduction of reflexes elicited by surgical stimuli. During one-day surgery procedures, patients are admitted to a clinic in the morning, optionally diagnosed (e.g. during an endoscopic examination), operated on, and, a few hours later, after regaining consciousness, they are released home for further treatment. Unfortunately, even safe and popular anaesthetics (e.g. propofol) produce mild cogni-

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tive disturbances, which can persist for a short time after the operation has been completed. Anaesthetised patients may experience dizziness, problems with fine movements, eye-hand coordination, and drowsiness — disrupting the so-called street fitness that is important in negotiating traffic and patient safety [1]. According to Dressler et al. [2], psychomotor functioning (assessed with the Short Performance Test) decreases for a period of up to 90 min after propofol has been administered. Similarly, a Polish paper reports that psychomotor functioning (assessed with the ATB Cross-Shaped Apparatus) recovered as soon as 1.5 h after propofol administration [3], which is consistent with Riphaus et al. [4]. Reports examining the negative consequences of anaesthesia have concentrated mainly on disturbances in psychomotor skills. The few studies that have examined disturbances in verbal functioning have indicated impairment in: verbal memory and shallow processing retrieval (as induced at the time of encoding) for six hours after surgery, and in deeper processing retrieval for 24 hours after general anaesthesia with propofol and alfentanil [5]. Studies concerning postoperative delirium, and/or cognitive dysfunction with the Revised Wechsler Adult Intelligence Scale, the Symbol Digit Modalities Test, and the Rey Auditory Verbal Learning Test present an assessment of significantly more complex functions [6]. The incidence of postoperative cognitive deficit (mostly after cardiac surgeries) in the verbal area was tested with a semantic fluency tool — the Verbal Fluency Test, the day before, and five days after, the surgery [7].

Dysfunctions in the verbal area are also represented by acquired dyslexia, which refers to a situation when a previously skilled reader loses the ability to read [8, 9]. Studies have shown that in a transparent orthography, word reading can be preserved and non-word reading impaired [10]. The acquired phonological dyslexia and dysgraphia may result from damage to the left perisylvian cortex [11] due to encephalitis, head injury or stroke. Further rehabilitation has been shown to improve reading abilities in a 6 to 10 year follow-up [12]. Various types of training have covered the conversion of graphemes to phonemes [13], as well as phonemes to graphemes [14]. Also, a behavioural treatment designed to strengthen phonological skills supporting reading and spelling helped to overcome weaknesses [15].

If the existence and scope of reading problems after anaesthesia could be properly recognised, the appropriate supporting procedure could also be implemented. However, the influence of anaesthetics on phonological processing has not been widely discussed in the medical literature.

The aim of our study was to examine phonological functioning i.e. reading speed and accuracy displayed by hospital patients under general anaesthesia administered during colonoscopy. We used a test assessing pure phonological processing, without referring to the meaning of the words.

This study presents the patients' state immediately after general anaesthesia procedures.

METHODS

This study was performed with permission from the local bioethical committee (Bioethical Committee of Poznan University of Medical Sciences, Permission No. 427/10, May 6, 2010).

45 individuals treated in the gastroenterology wards of Poznań University of Medical Sciences were assigned into two groups: those who underwent colonoscopy under intravenous anaesthesia were the Anaesthesia Group (AG) (n = 22), and 23 patients who had been hospitalised, but not anaesthetised, formed the Control Group (CG)

Every patient was assessed with a screening procedure (the Mini-Mental State Examination, MMSE; the Sense of Coherence Meaningfulness Subscale, SOC-29) [16, 17].

Immediately prior to colonoscopy, the AG patients were premedicated with oral midazolam 0.1–0.15 mg kg^{-1}, and transferred to the operating room. If the patients suffered from anxiety before the procedure, they were additionally sedated with midazolam 1–2 mg i.v. in order to alleviate anxiety and to achieve a similar second level of preoperative sedation according to the Ramsey Score (a patient is co-operative, oriented, and tranquil). The AG patients were anaesthetised with propofol 1–2 mg kg^{-1} i.v. Analgesic doses of fentanyl 1–2 µg kg^{-1} i.v. were administered. All the patients were anaesthetised to a similar clinical level (loss of eyelash reflex) with preserved spontaneous breathing. During the anaesthesia, vital signs were monitored as a standard procedure and no adverse events were observed. 1,000 mL of balanced crystalloid was infused continuously to prevent dehydration. The patients were released to the ward with stable vital signs when they had achieved 9–10 pts according to the Aldrete Score. This system assigns a score of 0, 1, or 2 to activity, respiration, circulation, consciousness, and colour, giving the maximum score of 10. A score of 9 indicates sufficient recovery for the patient to be transferred back to the surgical ward.

During the study, we administered Bogdanowicz's Łatysz test [18], which measures skill in decoding pseudowords. This test contains 71 non-words of varying difficulty, ranging from one-syllable, e.g. 'ni', to four-syllable words, e.g. 'przyjemije', which have no lexical referents, but follow the rules of Polish phonology and morphology. Single words were printed in black, on separate white cards. The basic index is the number of words read correctly within a time limit of 60 seconds, with a possible score of between 0 and 71 points, which is used as a measure of reading speed. The number of words read correctly, without any distortions, was a measure of reading accuracy. The additional accuracy index (the number of non-words read correctly, without any distortions, divided by the total number of non-words read within 60 seconds) was also computed. In this calculation, the maximum score is 1 (all words read correctly). Test scores are highly stable. However, if the assessment is repeated in a short period of time, the results are likely to be higher than in the first trial, even though the non-words will not be memorised. Improvement can be observed in reading speed rather than accuracy. The test assesses decoding without referring to the meaning. It measures 'pure' phonological processing without the participation of other linguistic skills, i.e. lexical, syntactical, or memory of familiar words. Education and gender are factors influencing the score.

The AG read pseudowords during four sessions: one preoperative, and three postoperative ones: 1.5, 3, and 6 h after the anaesthesia subsided. The CG were tested at identical time spans.

STATISTICAL ANALYSIS

The groups' demographic data was analysed with the χ^2 test. The results of the Łatysz test were presented as means ± SD. The results of the 'Łatysz' test in particular sessions were compared between the groups by means of the *t*-test. The distribution of accuracy and reading speed were analysed with the *W* Shapiro-Wilk test. All postoperative data was converted into *z*-scores with means and standard deviations obtained for each age group in the first preoperative session with the subsequent ANOVA. In all the tests, $P < 0.05$ was considered to be statistically significant.

RESULTS

Mean patient age was 43.1 ± 17.1 years (range: 19 to 77). There were 22 individuals (16 females and six males) who underwent colonoscopy under intravenous anaesthesia in the Anaesthesia Group (AG), while 23 patients (18 females and five males) hospitalised, but not anaesthetised, formed the Control Group (CG). All subjects were native speakers of Polish. The education level of the groups was comparable: two participants (AG: 0, CG: 2) had received primary education, four (AG: 3, CG: 1) —vocational education, 25 (AG: 10, CG: 15) were high school graduates, and 12 university undergraduates or graduates with a degree (AG: 7, CG: 5). They were matched by age ($P = 0.82$), gender (χ^2 $NW = 0.67$), and educational level (χ^2 $NW = 0.26$). None of the participants presented either symptoms of cognitive impairment or depression.

The preoperative results (first session), regarded as the baseline, showed no significant differences in performances between the AG and CG in the Łatysz test:

- for the reading accuracy, as computed with the total of all words pronounced correctly:
  - AG: 46.09 ± 13.33; 65% of words pronounced correctly,
  - CG: 51.04 ± 12.71; 72% of words pronounced correctly ($P = 0.21$).
- for the reading speed, as computed with the total of all words read:
  - AG: 48.86 ± 12.84,
  - CG: 54.65 ± 10.71 ($P = 0.11$).

Nobody read all the words correctly, while only four participants read all the words within the time limit of 60 seconds. The distribution was normal ($P = 0.45$ for accuracy, $P = 0.47$ for the reading), which suggests that the task difficulty level was appropriate. However, the older participants, aged ≥ 35 years, (45.27 ± 11.62) decoded the words less accurately than the younger ones (53.21 ± 13.93) ($P = 0.04$) and were slower: 48.42 ± 10.84 vs 56.47 ± 12.27, respectively ($P = 0.02$). Therefore, all postoperative data was converted into *z*-scores using means and standard deviations obtained for each age group in the first preoperative session (see Table 1).

Negative values demonstrated a decrease in phonological processing from the baseline (first session results). The analysis of *z*-scores revealed that this decrease both in reading accuracy and reading speed was observed after 1.5 h only in the AG in the participants aged ≥ 35 years. After 3 h, they regained the baseline values both in reading accuracy and reading speed.

A mixed analysis of variance (ANOVA) was computed on the postoperative *z*-score with group (AG vs CG) as the interindividual factor, and trials (1.5 h, 3 h, 6 h) as the intraindividual factor. The planned comparisons were made to further examine the differences.

Table 1. The postoperative performance (*z*-scores) in phonological processing of anaesthetised patients (AG) and controls (CG), mean ± SD

	All words pronounced			Words pronounced correctly		
	H1.5	H3	H6	H1.5	H3	H6
AG < 35 yr	0.02 ± 1.23	0.36 ± 1.16	0.62 ± 1.13	0.03 ± 1.21	0.34 ± 1.21	0.61 ± 1.17
AG ≥ 35 yr	–0.28 ± 0.85	0.14 ± 1.07	0.22 ± 1.01	–0.29 ± 0.89	0.06 ± 1.08	0.18 ± 1.04
CG < 35 yr	0.58 ± 0.68	0.78 ± 0.54	0.84 ± 0.48	0.47 ± 0.84	0.64 ± 0.73	0.72 ± 0.76
CG ≥ 35 yr	0.62 ± 0.98	0.90 ± 0.91	0.98 ± 1.00	0.60 ± 1.15	0.69 ± 1.10	0.77 ± 1.15

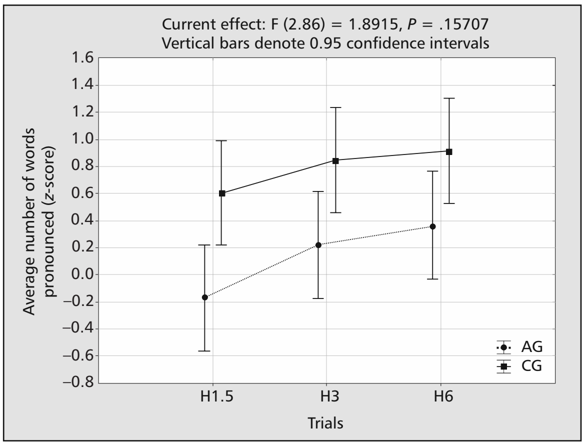

Figure 1. All words read within a minute — the reading speed in AG (anaesthetised patients) vs CG (controls) by ANOVA at 1.5, 3 and 6 hours (H) after anaesthesia

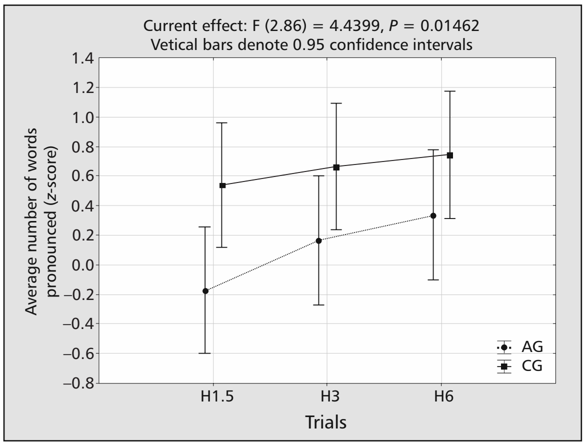

Figure 2. All words read correctly within a minute — the reading accuracy in AG (anaesthetised patients) vs CG (controls) by ANOVA at 1.5, 3 and 6 hours (H) after anaesthesia

The results of the reading speed showed a significant effect of both factors: group ($P = 0.02$), and trial ($P < 0.01$). The AG were significantly slower than the CG after 1.5 h ($P < 0.01$), after 3 h ($P = 0.03$), and after 6 h ($P = 0.05$).

As illustrated in Figure 1, the reading speed in the AG improved between 1.5 h (–0.17 ± 0.99) and 3 h (0.22 ± 1.08), $P < 0.01$, but not between 3 h and 6 h (0.37 ± 1.05), $P = 0.07$. Similarly, the reading speed in the CG improved between 1.5 h (0.60 ± 0.83) and 3 h (0.84 ± 0.74), $P < 0.01$, but it did not between 3 h and 6 h (0.91 ± 0.78), $P = 0.39$. 17 participants were able to read all the words (seven in the AG and ten in the CG) within the time limit of 60 seconds.

The results of the reading accuracy showed a significant effect of the trial ($P < 0.01$), and interaction between the group and trial ($P = 0.01$). The AG were less accurate than the CG after 1.5 h ($P = 0.02$), but not after 3 h ($P = 0.11$), and after 6 h ($P = 0.19$).

As illustrated in Figure 2, the reading accuracy in the AG improved both between 1.5 h (–0.17 ± 1) and 3 h (0. 17 ± 1.11), ($P < 0.01$), and between 3 h and 6 h (0.34 ± 1.09), ($P = 0.01$). Conversely, the reading accuracy in the CG improved between 1.5 h (0.54 ± 0.99) and 3 h (0.66 ± 0.92), ($P = 0.01$), but not between 3 h and 6 h (0.75 ± 0.96), ($P = 0.21$). This suggests that the optimal accuracy was achieved by the CG in the third consecutive trial (earlier than in the AG). In the last assessment session, the AG pronounced 82% of the words correctly, while the CG group pronounced 74% of the words correctly.

DISCUSSION

We found that decoding skills were impaired by general anaesthesia administered during endoscopic procedures. At 1.5 h after the procedure, the AG read the list of non-words in a slower and less accurate manner than the CG. Moreover, after 3 h and 6 h the AG performance was still slower, though not less accurate, than the CG performance. Propofol, fentanyl, and midazolam suppress the laryngeal and pharyngeal responses, which are crucial to vocalisation [19–21]. However, the pharmacokinetic properties of a hypnotic agent seem to exclude such a possibility — propofol disappears from the effectory compartment after several minutes and its metabolites are inactive. The same applies to fentanyl. Midazolam used for premedication could have had an impact on the laryngeal reflexes, as the half time of its activity is 1.5–2 hours, and the residual activity may have caused the occurrence of the described phenomena (midazolam was administered approximately 0.5 hour before the procedure, and it took 3–4 half-lives for it to be cleared from the blood). During the tests, the quality of speech remained unaffected, and the laryngeal and pharyngeal reflexes were intact: the patients drank and ate without aspiration to the respiratory tract. Many anaesthetic procedures involve airway tract manipulations, such as endotracheal intubation or Laryngeal Mask Airway ™ placement, which impair the function of the larynx for several hours after the anaesthesia, even without a visible swelling [22]. However, they were not applied to the patients tested in our study. But, as has been reported by Caranza et al. [23], complete recovery and awareness after general anaesthesia do not prevent silent aspiration, which may contibute to the impaired speed and accuracy of speech. Therefore, inferior performance in reading non-words might be due both to phonological and motor impairment of speech organs. In addition, the procedure causes an inflammatory response. The mutual relationship between the intensity of the inflammatory status and the postoperative cognitive dysfunction has become more evident over the last couple of years. Nevertheless, the balance between the protective and toxic qualities of different anaesthetics (volatile and intravenous ones) remains to be defined [24, 25]. Each violation of human homeostasis promotes the inflammation, so even low-aggressive procedures such as endoscopy may cause a rise in cytokines, thus affecting cognition in the early postoperative period. Further studies assessing the relationship between the level of inflammatory markers occurring after one-day surgery procedures and the test results could give us a better insight into the nature of the problem.

Our results show that although the quality of phonological processing is recovered fairly early (after 3 h) after propofol has worn off, its speed remains impaired even 6 h after the procedure, which partly contradicts the results assessing psychomotor functions. For example, Riphaus et al. [4] examined the quality of recovery after anaesthesia with the administration of fentanyl and propofol to 100 patients undergoing endoscopic procedures. The participants recovered their performance in the Number Connecting Test and driving simulator two hours after the procedure. Chung et al. [26] demonstrated that the recovery assessed with a driving simulator, polysomnography, and subjective scales allowed safe driving only after at least 24 hours following anaesthesia with fentanyl, midazolam, and propofol. The choice of a drug used during anaesthesia is crucial to fast recovery afterwards, and this means that there is a need for further studies comparing the effectiveness of cognitive recovery after the administration of different anaesthetic schemes.

Our results also show that older patients (≥ 35 years) reacted differently to the younger ones (≤ 35 years), as they manifested a decrease in phonological processing from the baseline both in reading accuracy and reading speed. After 3 h they regained the baseline values both in their reading accuracy and reading speed. This finding prompts differentiation of the postoperative recovery assumptions for different age groups.

As predicted, the experience factor influenced the improvement of the reading speed both in the AG and CG throughout the subsequent trials at 1.5 h and 3h after the anaesthesia subsided. Unexpectedly, the reading accuracy also improved towards the final session. This may have been caused by familiarity with the procedure, requiring the participants to read atypical material. Despite the possible influence of experience, we still observed significant differences between the treatment groups in their accuracy after 1.5 h, and in their speed in all the sessions.

Characteristically, all unfamiliar non-words may be pronounced correctly in Polish (with only one correct version possible) on the basis of general phonetic rules. This was illustrated by a relatively high accuracy rate (e.g. 65% and 72% of correct spelling for the AG and CG, respectively, in the last assessment session) despite substantial time constraints. Additionally, culture determines the articulative efficiency associated with the spoken language. The articulation time and short-term memory span differ significantly when dealing with numbers in languages from various language groups [27, 28].

Our data should be considered as an initial report and introduction to a more complete and wider problem analysis, as our sample was small, imbalanced in term of gender, and there was a wide range of participant ages. Also, we did not monitor the depth of anaesthesia or verify the learning disability report. However, both our groups performed the non-words reading task up to the standard preoperatively, which suggest that their reading abilities were equal.

Snowling and Hulme [29] differentiate between speech processing (phonology, involved in word recognition), and language processing (critical to language comprehension) as the prerequisites for correct reading. Coltheart's [30] dual-route theory of reading suggests that there is a lexical strategy (one that consults the mental lexicon) and a non--lexical strategy (one that does not consult the mental lexicon). The latter is used to decode an unfamiliar letter sequence. Thus, part of the linguistic knowledge is the ability to comprehend how single sounds are used in a language and what the rules of their combination are [31]. The reader sequentially converts graphemes into phonemes and blends them. Event-related fMRI provides evidence for dual-route models of visual word processing [32].The test we administered, i.e. the Łatysz, is a trial designed to examine the non-lexical reading strategy. This is used to assess dyslexia in primary and secondary school students and as such it is included in the set of dyslexia diagnostic tools normally administered in Polish state counselling centres. However, it has also been employed for adults' reading assessment [33].

The research may be used as a prompt for further, more detailed studies. We suggest extending the observation time up to 12 hours in order to detect patients' full recovery, comparing different anaesthetic schemes with thorough monitoring of the depth of basic sleep and the duration of anaesthesia, which could provide a better insight into the stability of anaesthesia.

The popularity of one-day surgery is increasing because of external out-patient procedures, less invasive surgical treatments, and financial benefits for the national healthcare system. Even temporary cognitive impairments induced by anaesthesia must be identified for patients' health and well-being.

CONCLUSION

The assessment of phonological impairment is an important examination of a patient's clinical state, because it can influence the acquired difficulties in reading and writing. We observed that patients who underwent colonoscopy under general anaesthesia manifested impaired phonological functioning both in terms of the speed and accuracy of reading non-words shortly after the procedure. However, the accuracy problems soon subsided, whereas the speed impairment persisted.

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