CoBeN

Novel Network-Based Approaches for Studying Cognitive Dysfunction in Behavioural Neurology

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D3.3 Novel parametrization software for kinematic analysis

Work Package:	WP3
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1 Introduction

In the frame of this deliverable, we aimed to design and implement a novel online handwriting parameterization system that will enable to perform a complex quantification of graphomotor disabilities and cognitive deficits manifested in several neurodegenerative disorders. The software is freely available (under the MIT license) upon request (http://coben.ceitec.cz/software/) and will help the community to perform objective analysis of handwriting/drawing in e.g. Parkinson's (PD) or Alzheimer's disease (AD).

2 Methods

Based on a comprehensive literature review we firstly identified a set of possible disorders and cognitive deficits that could be present in PD and/or AD. In the second step, we designed a new multilingual handwriting/drawing acquisition protocol, that will help to perform a complex assessment of these disorders (this was done in the frame of the deliverable D3.1 Pilot data for kinematic assessment and analysis released). Next, in the frame of this deliverable, we identified parameters (measures) that could quantify the identified disorders (those, that are too difficult to be quantified by a computer – e.g. assessment of the overall product – were omitted). Finally, the remaining set of parameters was coded in Matlab and the functions were grouped into one toolbox (deliverable D3.3).

3 Results

CoBeN online handwriting/drawing parameterization toolbox is a set of Matlab functions that enables to perform complex quantification of graphomotor disabilities and cognitive deficits that are mainly manifested in Parkinson's and/or Alzheimer's disease. A list of these parameters and related Matlab functions can be found in Table 1. This toolbox will help neurologists or clinical psychologists to get a quick and comprehensive insight about a pathology present in the process/product of handwriting/drawing. The toolbox is tuned for signals digitized by devices using 150 Hz sampling frequency and 2540 lpi resolution, e.g. Wacom Intuos Pro. The handwriting data must be stored in the *.svc format. The toolbox contains a demo file demonstrating parameterization a sentence.

The toolbox is available upon request (irena.rektorova@ceitec.muni.cz) under the MIT license. It has been developed for Matlab R2014b.

Table 1: Specific handwriting/drawing disorders and Matlab functions that are used to quantify them (Feature name format INF: DIR–FN (HL), where INF stands for processed information (ON for on-surface, AIR for in-air, PRESS for pressure, TILT for tilt, and AZIM for azimuth), DIR denotes direction (G for global, H for horizontal, and V for vertical), FN contains feature name, and HL a statistic, that is used for transformation to a scalar value. For example, AIR: V-ACC (mean) means mean of vertical acceleration during in-air movement.)

Specific disorder	**Task**	**Parameter**	**Feature definition** ***Name of the related Matlab function***
Higher duration of writing/drawing	Graphemes "l", connecting two dots,	ON: DUR	Duration of on-surface movement. *Function (file)*: writing_analysis.m

	sentence, Archimedean spiral, pentagon copy test		
Memory and/or visuospatial deficits	Sentence, pentagon copy test	AIR: DUR	Duration of in-air movement. *Function (file)*: writing_analysis.m
Dysfluency in line (a line/stroke is associated with stuttering, freezing, tremor or unevenness)	Graphemes "l", connecting two dots, sentence, Archimedean spiral, pentagon copy test	ON: {H,V}–SNRX	Signal-to-noise ratio of vertical and horizontal movement projection. *Function (file)*: writing_snr.m
	Archimedean spiral	DoS	Degree of spiral drawing severity (San Luciano et al. 2016). *Function (file)*: spiral_features.m
		2ndSm	Second order smoothness (San Luciano et al. 2016). *Function (file)*: spiral_features.m
		1stZC	First order zero crossing (San Luciano et al. 2016). *Function (file)*: spiral_features.m
Dysfluency in time (big variations in velocity profile)	Graphemes "l", connecting two dots, sentence, Archimedean spiral, pentagon copy test	ON: NCV	Number of changes in the velocity profile. *Function (file)*: writing_speed.m
		ON: RNCV	Relative number of changes in the velocity profile. *Function (file)*: writing_speed.m
Progressing fatigue	Sentence	ON: SDUR (slope)	Slope of the duration of strokes on-surface. *Function (file)*: stroke_analysis.m
		AIR: SDUR (slope)	Slope of the duration of strokes in-air. *Function (file)*: stroke_analysis.m
		SDURR (slope)	Slope of ratio of the on-surface/in-air stroke duration. *Function (file)*: stroke_analysis.m
Low velocity	Graphemes "l", connecting two dots, sentence, Archimedean spiral, pentagon copy test	ON: {G,H,V}–VEL (mean)	Mean velocity. *Function (file)*: writing_speed.m
		ON: {G,H,V}–VEL (max)	Maximum velocity. *Function (file)*: writing_speed.m
Low acceleration	Graphemes "l", connecting two dots, sentence,	ON: {G,H,V}–ACC (mean)	Mean acceleration. *Function (file)*: writing_speed.m
		ON: {G,H,V}–ACC (max)	Maximum acceleration. *Function (file)*: writing_speed.m

	Archimedean spiral, pentagon copy test		
Lower variability of velocity	Graphemes “l”, connecting two dots, sentence, Archimedean spiral, pentagon copy test	ON: {G,H,V}–VEL (std)	Standard deviation of velocity. *Function (file)*: writing_speed.m
Lower variability of acceleration	Graphemes “l”, connecting two dots, sentence, Archimedean spiral, pentagon copy test	ON: {G,H,V}–ACC (std)	Standard deviation of acceleration. *Function (file)*: writing_speed.m
Gradually decreasing velocity	Graphemes “l”, sentence, Archimedean spiral	ON: {G,H,V}–VEL (slope)	Slope of velocity profile. *Function (file)*: writing_speed.m
Gradually decreasing acceleration	Graphemes “l”, sentence, Archimedean spiral	ON: {G,H,V}–ACC (slope)	Slope of acceleration profile. *Function (file)*: writing_speed.m
Too high pressure on the pen tip	Graphemes “l”, connecting two dots, sentence, Archimedean spiral, pentagon copy test	PRESS (mean)	Mean pressure. *Function (file)*: read_SVC_file.m
Very low pressure on the pen tip	Graphemes “l”, connecting two dots, sentence, Archimedean spiral, pentagon copy test	PRESS (mean)	Mean pressure. *Function (file)*: read_SVC_file.m
Unstable pressure on the pen tip	Graphemes “l”, connecting two dots, sentence,	PRESS (rstd)	Relative standard deviation of pressure. *Function (file)*: read_SVC_file.m

	Archimedean spiral, pentagon copy test		
Disability to perform longer strokes (frequent interruptions and pen elevations)	Sentence, Archimedean spiral	NINT	Number of interruptions. *Function (file)*: number_of_interruptions.m
Instability in amplitude of letters (micrographia)	Graphemes "l"	ON: V–LMAX (rstd)	Relative standard deviation of local maxima in vertical projection. *Function (file)*: local_analysis.m
Instability in inclination of letters	Graphemes "l"	AZIM (rstd)	Relative standard deviation of azimuth. *Function (file)*: read_SVC_file.m
Unstable tilt of pen	Graphemes "l", sentence, Archimedean spiral	TILT (rstd)	Relative standard deviation of tilt. *Function (file)*: read_SVC_file.m
Unstable density (unstable distance between letters, words, threads of a spiral)	Archimedean spiral	ON: SPI	Spiral precision index (Cascarano et al. 2019). *Function (file)*: spiral_features.m
		TGHTNS	Spiral tightness (San Luciano et al. 2016). *Function (file)*: spiral_features.m
		SWVI	Variability of spiral width (San Luciano et al. 2016). *Function (file)*: spiral_features.m
	Sentence	ON: NIAI	Number of on-surface intra-stroke intersections. *Function (file)*: intersection_analysis.m
		ON: RNIAI	Relative number of on-surface intra-stroke intersections. *Function (file)*: intersection_analysis.m

4 Conclusion

In the frame of this deliverable, we introduced a new software of graphomotor disabilities/cognitive deficits parameterization. The software is novel especially in a way that it enables objective and very complex assessment of handwriting/drawing issues associated with neurodegenerative diseases. The parameters were selected based on a comprehensive review, are clinically interpretable and can support neurologists or clinical psychologists in e.g. differential analysis, early diagnosis, treatment effect monitoring, etc.

5 References

Cascarano, G. D., Loconsole, C., Brunetti, A., Lattarulo, A., Buongiorno, D., Losavio, G., ... & Bevilacqua, V. (2019). Biometric handwriting analysis to support Parkinson's Disease assessment and grading. BMC Medical Informatics and Decision Making, 19(9), 252.

San Luciano, M., Wang, C., Ortega, R. A., Yu, Q., Boschung, S., Soto-Valencia, J., ... & Saunders-Pullman, R. (2016). Digitized spiral drawing: A possible biomarker for early Parkinson's disease. PloS one, 11(10).