Neuro-Abilities and a Good Life

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Abstract

Background: Neuro-based scientific and technological advancements constantly shape and are shaped by body/mind ability expectations, which in turn influence the perception and meaning of below species-typical (impaired), species-typical (normal) and beyond species-typical abilities (enhanced), which neuro-abilities are desired, and what neuro-ability-related actions are taken. Neuro-abilities from below to beyond species-typical abilities impact many indicators of well-being, or in other words the ability to have a good life. Disabled people experience barriers to a good life, many of which are outlined in the United Nations Convention on the Rights of Persons with Disabilities. Therefore, it is of importance to disabled people how neuro-advancements and neuro-ability expectations are governed. Ability-based theoretical concepts could be used to discuss and analyze in a systematic fashion neuro-ability expectation dynamics, the impact of neuro-advancements and human enhancements including neuro/cognitive enhancements on the ability to have a good life and contribute a unique lens to neuroethics, neurotechnology governance and ability expectation governance efforts.

Methods: In this study an online survey approach was used to ascertain the views of first-year undergraduate disability studies students on the impact of neurotechnologies, neuro/cognitive enhancements and human enhancements on the good life and the impact of being a disabled person in general and belonging to another marginalized group on experiencing a good life. Neuro-focused academic abstracts obtained from Scopus, Web of Science, and the 70 databases of EBSCO-HOST were searched for the presence of ability-based concepts.

Results: Students indicated that: 1) Disabled people will be increasingly impacted in a positive way by human enhancements and neurotechnologies; 2) Disabled people in general and even more if they belong also to another disadvantaged group experience a lower level of or are more impacted by most of the indicators of the four composite well-being measures (Social Determinants of Health; Canadian Index of Well-being, OECD Better Life Index and World Health Organization Community-Based Rehabilitation Matrix) than non-disabled people; and 3) More indicators of well-being of the four composite well-being measures are impacted by neurotechnologies and neuro/

cognitive enhancements than not impacted. The review of the academic abstracts indicated that ability-based concepts were not used to discuss neuro-advancements or neuro- enhancements.

Conclusions: The findings of this study suggests that an in-depth engagement with the impact of neuro-advancements on the ability for a good life, especially in relation to disabled people, is warranted as is the use of ability-based concepts as an analytical lens.

Keywords: Abilities; Neuro-abilities; Good life; Neurotechnology; Neuroenhancement; Well-being; Ability-based concepts; Disabled people; People with disabilities; Intersectionality

Introduction

Well-being is essential for the ability to have a good life [1] and has many social determinants [2]. Neuro-advancements including neuro/cognitive enhancements raise many social issues [3-12] and with that impact the good life on many levels. Neuroethics and neurotechnology governance discourses emerged to decrease or prevent the negative impact of neuro-advancements [3, 4, 11, 13-17]. Disabled people are one main target group for neuro-advancements including neuro/cognitive enhancements [12, 18-23], whereby the use of neuro-products is often contested such as in the case of cochlear implants [12, 24-28]. In a recent study [2], it was found that the academic literature covering 50 neurotechnologies (50 NT) and neuroenhancements mentioned only one of the 17 composite measures of well-being examined, namely the "social determinant of health". Furthermore, the study [2], found that the same literature engaged very unevenly with the 111 indicators of four of these composite measures (OECD Better Life Index, the Canadian Index of Well-being, the World Health Organization initiated Community-Based Rehabilitation Matrix and the Social Determinants of Health [2]. To follow up on the former study [2], participants from one Canadian undergraduate disability studies class were asked four research questions: 1) What is the impact of human enhancements beyond the species-typical on the ability to have a good life (today) and in the future? 2) What is the impact of neurotechnologies on the ability to have a good life (today) and in the future? 3) What is the impact of being a disabled person in general, and belonging to another marginalized group on top of being a disabled person, on experiencing a good life, as indicated by the 111 indicators of the four well-being composite measures (Social Determinants of Health; Canadian Index of Well-being, OECD

Better Life Index and World Health Organization Community-Based Rehabilitation Matrix)? 4) What is the impact of neurotechnologies and neuro/cognitive enhancements on the 111 indicators of the four well-being composite measures?

Ability-based judgments, norms and conflicts are a general cultural reality. One study found that participants believed that different social groups select different abilities as abilities needed for a good life [29], suggesting the possibility of ability-based conflicts between different groups. Ability-based studies [30-37] have generated many ability-related concepts [32, 38-47], which could be used to discuss and analyze in a systematic fashion the impact of neuro-advancements including neuro/cognitive enhancements on the ability narrative and the ability to have a good life contributing to neuroethics, neurotechnology governance and ability expectation governance efforts. Therefore, while searching the abstracts of the academic databases EBSCO-HOST (an umbrella database that includes over 70 other databases itself), Scopus, and Web of Science, the fifth research question was: How often are ability-focused concepts mentioned in the literature focusing on neurotechnologies and neuro/cognitive-enhancements?

Neurotechnologies and neuro/cognitive enhancements: disabled people and beyond

Neurotechnologies become increasingly accessible for medical, non-medical and do-it-yourself (DIY) purposes [11]. Neuroethics is still a topic [48, 49] including the nature [50] and diversity of neuroethics [51] and translational neuroethics [52]. Topics discussed under neuroethics in recent times ranged from dealing with "existing sexist and androcentric biases within neuroscientific research" [53] and the ethics of neuroscience [54] to invasive neurotechnologies [55] and that ethics has to be included in neuro-engineering education [56]. Ethics in general has recently been covered in relation to neuro-advancements, for example, in regard to the use of neurotechnologies in education [57], human enhancement [58-60], equitable access to neurotechnologies [61], diversity of stakeholders [62], and socially aligned networks [63]. A recent study interviewing DIY neurohackers found the following motivations for DIY neurohacking: "In short, neurohackers might simultaneously seek to manage a physical or psychological condition and to experiment with implants that open doors, pay bills or give them new senses. And blur the line between therapy and enhancement" [11].

Disabled people are one of the main user targets for neuro-interventions [18-22], especially brain-computer interfaces [64-66], often under the header of assistive technologies [67]. Furthermore, what counts as a neuro-impairment constantly shifts. To give a historical example, the very term learning disability with the meaning of neurological disorder was coined in North America in 1963 [68] in the aftermath of ability expectations changes in schools [69-71].

A recent study of the views of neurohackers revealed that none saw any negative effects, and eight of the thirteen neurohackers saw positive effects of neurotechnologies for disabled people [11]. As to the positive effect mentioned "Neurotech-

nologies-related body modification will cause people to overcome ableism because in the future people will understand that everyone is disabled (when they have no neurotechnology), so there will be no distinction between abled and disabled people, transforming the concept and self-concept of disability as such, both at the individual and social level. Another person mentioned that partially disabled people or people with autism could be provided with ways to better communicate with other people; another said that specific technical solutions (like Internet of Things (IoT) in conjunction with neurotechnologies) will help the blind to better orient themselves; and still another foresaw that amputees will be have more functional prosthetic limbs that are not designed to fake a real limb but that highlight the prosthetic limb and their (additional) technical functionality (e.g., a prosthetic arm with a drone and other features)"[11].

However, others note issues around how neuro-advancements are applied to disabled people, including the imagery used to describe disabled people [12, 23, 72-77].

A recent study on neurohacking found another motivation: "Improving other people's lives or working for a greater good" [11].

The ability of disabled people to have a good life can be impacted by neuro-advancements, including neuro/cognitive enhancements beyond the species typical in several ways: 1) By non-therapeutic use of a product (consumer angle); 2) By therapeutic use of a product (patient angle); 3) By changing societal parameters caused by humans using neuro-enabled enhancements beyond the species typical (e.g., changes in ability expectations); 4) By changing societal parameters demanded and caused by neuro-enabled enhancements beyond the species typical governance and activism; 5) By being a potential argument used in neuro-enabled enhancements beyond the species typical governance and activism (modified from [1]).

Given the potential impact of neuro-advancements on the ability to have a good life, the first aim of this study was to ascertain the views of participant on the impact of neurotechnologies and neuroenhancements on the ability to have a good life for disabled people and beyond.

Neuro and the indicators of well-being

Numerous neuro-applications including neuro/cognitive enhancements are seen to advance well-being [1, 60, 78-91]. Well-being of people and society is a main part of the ability to have a good life [92-95]. Various tools exist to analyze the well-being of a population and individuals [2], such as the four composite well-being measures: Social Determinants of Health, Canadian Index of Well-being, OECD Better Life Index and the World Health Organization Community-Based Rehabilitation Matrix [92, 96-99]. Marginalized individuals and groups are known to encounter problems in relation to many social determinants of well-being and with that the ability to experience a good life. The content of the United Nations Convention on the Rights of Persons with Disabilities [100] suggests that disabled people experience a negative reality in regard to many of the indicators covered by the four composite measures of well-being (Social Determinants of Health, Canadian Index of Well-being, OECD Better Life Index, and the

World Health Organization Community-Based Rehabilitation Matrix).

Therefore, the second aim of this study was to ascertain student's views on the impact of being a disabled person in general and belonging to another marginalized group on top of being a disabled person, on experiencing a good life as reflected by the indicators of the four composite measures.

In a recent study [2], it was found that of the 17 tools to measure well-being, only the Social Determinant of Health tool was mentioned to a significant extent in conjunction with neurotechnologies and neuro/cognitive enhancements [2]. From the same study, it was reported that the academic literature that focused on 50 NT, which included brain computer interfaces, engaged very unevenly with the 111 individual indicators of four of these composite measures (Social Determinants of Health; Canadian Index of Well-being, OECD Better Life Index and World Health Organization Community-Based Rehabilitation Matrix).

Given the importance of the well-being measures, the third aim of this study was to ascertain the knowledge and sentiments students had on the impact of neurotechnologies and neuro/cognitive enhancements on the well-being indicators.

The lens of ability studies

Ability-based studies [30-37] have been investigating ability-based judgments, norms, and conflicts at least since 2008. Ability-based judgments and norms are a general cultural reality and are influenced by many factors such as scientific and technological advancements, which includes neuro-based scientific and technological advancements. Scientific and technological advancements generate new abilities humans can desire, and human desires for certain abilities shape research agendas to make these ability desires a reality [101]. Ability judgments can be categorized into four stages. The emerging/eclectic ability stage is the stage where an ability is emerging and is seen as best desirable by a small subset of a given group. Some of the emerging abilities can move to the next stage, the nice-to-have stage, where the ability is desired by many people as nice-to-have but not yet seen as essential. The third stage is the one where due to societal realities a given ability is judged as an essential ability to have (ableism). Given that the ability is seen as essential, this judgment can be used to enable social groups by guiding policies and research to enhance the ability for a good life. The capability approach [102] represents one view on essential abilities one needs to experience the ability to have a good life [103-108]. At the same time judging abilities as essential can also be used by social groups to disable other social groups, by setting up irrelevant abilities as essential, or by falsely claiming another social group does not have the abilities. The disabling use of ability judgment is for example used to justify disablism (negative treatment of disabled people), racism, sexism and other negative isms and negative ability expectations humans have of nature, and it plays itself out around how we judge human ability enhancements [31, 101]. Finally, there is a fourth stage (ability obsolescence), where an ability expectation becomes obsolete due to for example scientific and technological advancements (see

for example the origin of the Luddites [109]) or contemporary discussions around the impact of robotics, automatization and artificial intelligence on occupations [110-113].

Neuro-advancements including neuro/cognitive enhancements can influence and be influenced by the four stages of ability expectations. Ability-related theoretical concepts [32, 38-47] developed within ability-based studies [30-37] could be used to discuss and analyze in a systematic fashion the impact of neuro-advancements and human enhancements, which includes neuro/cognitive enhancements on the ability to have a good life, and on neuro-ability expectations contributing to neuroethics, neurotechnology governance and ability expectation governance efforts. Therefore, the fourth aim was to ascertain the use of ability-based theoretical concepts in neuro-focused academic literature.

Materials and Methods

Part 1: surveys

Study design and research questions

As a follow-up on a scoping review on the coverage of the impact of neurotechnologies on well-being and health equity [2], this study reports on the answers of a first-year, undergraduate disability studies class of one Canadian University to these research questions: 1) What is the impact of human enhancements beyond the species-typical on the ability to have a good life (today) and in the future? 2) What is the impact of neurotechnologies on the ability to have a good life (today) and in the future? 3) What is the impact of being a disabled person in general and belonging to another marginalized group on top of being a disabled person on experiencing a good life as indicated by the 111 indicators of the four well-being composite measures (Social Determinants of Health; Canadian Index of Well-being, OECD Better Life Index and World Health Organization Community-Based Rehabilitation Matrix)? 4) What is the impact of neurotechnologies and neuro/cognitive enhancements on the 111 indicators of the four well-being composite measures? As to neurotechnologies, students were given the same 50 NT-related terms used in the previous study [2], to keep in mind under the impact header 50 NT ("artificial brain", "artificial hippocampus", "auditory brainstem implant", "bionic eye", "brain computer interface", "brain feedback", "brain imaging", "brain stimulation", "brain to speech technology", "brain-to-text technology", "cochlear implant", "cognitive imaging", "cognitive stimulation", "collaborative cognitive simulations", "CoriQ electrocorticographic", "cortical modem", "cranial electrotherapy stimulation", "Darpa Ram senor", "deep brain stimulation", "direct acoustic cochlear implant", "ear-EEG", "EEG biofeedback", "electrocorticography", "exocortex", "facial electromyography", "God helmet", "hemoencephalography", "hippocampus prosthesis", "human computer interface", "intracranial electroencephalography", "muse headband", "neural stem cell", "Neuralink", "neurochip", "neuro-information", "neuro-modulation", "neurofeed-

back", "neuroimaging", "neurosensing", "neurostimulation", "nootropics", "optogenetics", "prosthetic memory device", "pulsed electromagnetic field therapy", "responsive neurostimulation", "sacral nerve stimulation", "speech brain computer interface", "spinal cord stimulator", "subvocal speech device", "THync mood altering headset", "transcranial direct current stimulation", "transcranial magnetic stimulation", "virtual reality" and "whole brain emulation").

Participants for surveys

From September to December 2021, weekly survey questions were given via the university Qualtrics online platform to students enrolled in a junior-level disability studies course (87 students). These questions were related to the weekly topics of the class, and students were required to submit their responses by the Friday before the following Monday's lecture for any given week. The survey questions used to answer research questions 1 and 2 were part of the week 4 topic "human enhancement", and the survey questions used to answer research questions 3 and 4 were part of the week 5 topic "health equity". The survey answers reflected the views of the students before they had access to the lectures covering the topics. The answers to the surveys were recorded every week and the survey answers were used as part of the lectures to stimulate discussions on the topic in the class. In compliance with the ethics approval from the University of Calgary Conjoined Health Ethics Board (REB 17-0785) the students were asked at the end of the course after the final marks of the course were submitted whether the data could be used (without identifying any student) for an academic study. The study was conducted in compliance with the ethical standards of the responsible institution on human subjects as well as with the Helsinki Declaration.

Disability studies students were chosen because students in general are seen as change agents [114-121], and disability studies students are concerned about the ability of disabled people to have a good life in sync with the field of disability studies, which investigates the lived experience of disabled people [122, 123]. Given the focus of the students and the academic field of disability studies, the topic of this study was of relevance to the participants, as neurotechnologies and neuro/cognitive enhancements beyond the species-typical are recognized to raise many social issues [3-10, 12-14], and with that impact the good life of disabled people and others on many levels. Knowing the answers of participants on the questions asked might be useful to tailor educational material in disability studies classes but also in classes that cover social implications of neuro-advancements such as neuroethics, neuro-engineering and science and society classes.

The questions selected for this study were chosen for the following goals. The first focus was to understand how participants perceived the effect of neurotechnologies and human enhancements including neuro/cognitive enhancements on the ability to have a good life. Framing the effects of these advancements in the context and indicators of a good life allowed students to relate neurotechnologies and human enhancements, including neuro/cognitive enhancements, to the lived good life experiences of disabled individuals, as well as other social groups, including themselves. This approach encouraged critical evaluation of neurotechnologies and human enhancements, including neuro/cognitive enhancements by establishing a connection between these neurotechnologies and human enhancements including neuro/cognitive enhancements and their real-world implications.

The second focus was on the effect of intersectionality in this case, the impact on the ability to have a good life (as judged by the indicators of the four well-being measures) if disabled people also belong to another marginalized groups (disabled women, disabled people from an ethnic minority, Indigenous disabled people, disabled people from the global south). Disability studies students are very aware that the ability to have a good life is even more hindered if the "disability" intersects with other marginalized characteristics, which make one disadvantaged. Intersectionality is a big topic within disability studies [124-132].

The third focus of the questions was on the impact of neurotechnologies and human enhancements including neuro/cognitive enhancements on the indicators of the ability to have a good life from the composite measures: the Better Life Index, the Canadian Index of Well-being, the World Health Organization initiated Community-Based Rehabilitation Matrix and the Social Determinants of Health. Giving students these well-being composite measures with their 111 indicators allowed students to think about the impact of neurotechnologies and human enhancements including neuro/cognitive enhancements on many concrete aspects of a good life whereby disability studies students are already aware that disabled people face problems in relation to many of the indicators, as evident by the content of the United Nations Convention on the Rights of Persons with Disabilities [100].

Data analysis

Frequency counts, percentage measures and means of the descriptive quantitative data were extracted and analyzed using Qualtric's intrinsic frequency distribution analysis capability.

Part 2: literature review

Human enhancements, neuro/cognitive enhancements and neurotechnologies increasingly enable the modification of existing and the creation of new body/mind abilities. Many ability-related concepts [32, 38-47] have been generated within the field of ability-based studies [30-37]. The very discussions around human enhancements, neuro/cognitive enhancements and many neurotechnologies are about missing body/mind abilities, old body/mind abilities being seen as obsolete (ability obsolescence [32, 47]), and new body/mind abilities being seen as useful. Existing ability-based concepts could be used to critically analyze the ability narrative and ability influence of human enhancements, neuro/cognitive enhancements and neurotechnologies. Therefore, the fifth research question was: How often are ability-based concepts mentioned in the literature that focused on the neurotechnologies and neuro/cognitive enhancements. On November 15, 2023, the abstracts of

the academic databases EBSCO-HOST (an umbrella database that includes over 70 other databases itself), Scopus and Web of Science were searched with no time restrictions. The databases were first searched for abstracts that contained the 50 NT terms listed above or the terms "neuroenhancement*" OR "neuro enhancement*" OR "neuro-enhancement*" OR "moral enhancement*" OR "cognitive enhancement*", generating two sets of abstracts. In the second step the two sets of abstracts obtained were each searched for the presence of 35 ability-based concepts, six human enhancement-linked concepts and six technology-focused ability concepts (terms not listed here but in the result section). The databases used were chosen because together they contain journals that cover a wide range of topics from areas relevant to answering the research questions. These databases contain the main disability studies journals and many journals that focus on science and technology including their governance. As to inclusion criteria, scholarly peer-reviewed journals were included in the EBSCO-HOST search, and reviews, peer-reviewed articles, conference papers, and editorials in Scopus and the Web of Science search were set to all document types. As to exclusion criteria, the abstracts had to be in English.

Limitations (surveys and literature review)

This study has various limitations. An online delivered survey instrument was used and as such students could not ask for clarifications. The surveys also did not contain questions that asked for qualitative content to investigate in depth the views of participants. Students were asked to keep in mind the 50 NT terms given to them as a total, and the survey did not ask students' views on individual neurotechnology. Different answers might have been obtained for different neurotechnologies. No demographic questions were asked because this was a standard graded course assignment designed to encourage student engagement with the course topics. To provide answers based on demographics would have entailed the danger of preventing a "we"-feeling of the group. Also, as students were asked at the end of the course whether their answers could be used for publication, asking for demographic might have increased the risk of students not giving their permission, as one might have been able to identify the person based on the demographics. Nevertheless, it is worth noting that this class, like all others in this degree program, is primarily comprised of female students. Answers as to the sentiment of students related to the impact of human enhancements and neurotechnologies on the good life were numbers of students, and only standard basic statistic (means, standard deviation) were used to interpret the student's answers. For the answers to the other survey-related questions, only the percent of responses were used with no statistical analysis. The answers are a snapshot of this particular class.

The literature review only covered English language literature and a certain set of databases. Results for both the surveys and the literature review are not generalizable but allow for some insight, which could facilitate further studies such as asking the same questions in other courses and other settings to see what the results would be.

Results

The results of this study are reported in four sections. In the first three sections, results from the surveys (tables in the result sections reflect the main take-home messages of the data, the tables with full data have been shown in the supplementary materials) are presented. In the fourth section the results of the literature review are presented.

As to the survey results, the main findings are that: 1) Most students indicated that human enhancements and neurotechnologies have an impact on the good life of all social groups they could choose from. Disabled people were identified as the group most positively impacted, with the trend increasing from in the moment to the future; 2) The majority of participants felt for the majority of the well-being indicators that disabled people are in a more problematic situation than non-disabled people, and that if disabled people also belong to another disadvantaged group, the problems increase; 3) More of the 111 indicators were identified as being impacted than not being impacted by neurotechnologies or neuro/cognitive enhancements. At the same time, the "do not know/no opinion" numbers were substantial indicating a lack of knowledge, whereby the "do not know" numbers were in general higher for the neurotechnologies than neuro/cognitive enhancements.

The results of the literature review indicate that ability-based concepts, techno-linked ability concepts, which were used to look at the social impact of technologies and enhancement linked concepts, were rarely or not at all employed to discuss neurotechnologies or neuro/cognitive-enhancements. Furthermore, although the term ability was present frequently, the term "neuroabilit*" or "neuro-abilit*" was not mentioned once.

Impact of human enhancement beyond species-typical and the 50 NT on the ability to have a good life of different groups now and in the future

To answer research questions 1 and 2, students were given a sliding scale of 0 - 10, with 0 indicating not being impacted, 1 being purely negative, 2 - 4 being more negative than positive, 5 being equal positive and negative, 6 - 9 being mostly positive, and 10 being purely positive impact to answer the research questions for different groups. In Table 1 (covering Supplementary Materials 1-4, www.neurores.org) and Table 2 (covering Supplementary Materials 5-8, www.neurores.org), only three numbers are shown, namely the no-impact, the means and the standard deviation. A higher means implies a higher positive impact on the good life.

Table 1 shows that students saw disabled people being most positively impacted, and that the "no impact" value was the lowest for disabled people. As to other groups, for example, people with high income moved from spot 4 for today to spot 2 for the future.

Table 2 shows that students saw disabled people being impacted the most positively, and that the "no impact" value was the lowest for disabled people. As to human based groups, people with low income were seen to be impacted the least positively.

Table 1. Students that Ticked off "No Impact" and the "Means" of Student Views on the Impact of Human Enhancement Beyond Species-Typical on the Ability to Have a Good Life of Different Groups Now and in the Future

Social group/entity	Impact of human enhancement beyond species-typical on the ability to have a good life in the moment		Standard deviation	Social group/entity	Impact of human enhancement beyond species-typical on the ability to have a good life in the future		Standard deviation
	0 for no impact as answer	Means of the answers			0 for no impact as answer	Means of the answers	
Disabled people	5.75%	7	2.47	Disabled people	1.15%	7.43	2.29
The elderly	12.64%	6.55	2.81	People with high income	8.05%	6.97	2.58
Countries of the North	10.47%	6.53	2.55	The elderly	5.75%	6.9	2.64
People with high income	14.94%	6.49	2.94	Countries of the North	5.75%	6.84	2.35
Youth	12.79%	6.22	2.68	Youth	5.81%	6.74	2.56
Women	11.63%	6.03	2.48	Post-secondary students	6.90%	6.72	2.47
Single parents	16.09%	6.03	2.76	Women	5.75%	6.6	2.32
Men	12.64%	5.98	2.49	Non-university apprenticeship students	6.90%	6.54	2.4
Nonbinary people	13.95%	5.97	2.65	Nonbinary people	9.30%	6.45	2.62
Family caregiver	14.94%	5.92	2.68	Men	6.90%	6.38	2.38
Post-secondary students	17.24%	5.91	2.79	Single parents	9.30%	6.31	2.49
Blue collar workers	13.79%	5.82	2.62	Family caregiver	9.30%	6.26	2.56
Countries of the South	12.79%	5.76	2.55	Blue collar workers	6.90%	6.26	2.54
Non-university apprenticeship students	17.24%	5.74	2.72	You	8.05%	6.24	2.46
People of ethnic background not a majority in Canada	17.24%	5.47	2.69	Countries of the South	8.05%	6.16	2.5
Immigrants to Canada	20.69%	5.37	2.76	People of ethnic background not a majority in Canada	9.20%	5.93	2.34
Indigenous people in Canada	16.09%	5.36	2.53	Immigrants to Canada	11.49%	5.86	2.47
People with low income	13.79%	5.24	2.52	People with low income	6.90%	5.82	2.62
You	20.69%	5.2	2.63	Immigrants to other countries	11.49%	5.79	2.49
Immigrants to other countries	20.69%	5.17	2.71	Indigenous people in Canada	8.05%	5.76	2.36
Animals	25.58%	4.83	2.99	Animals	20.69%	4.9	2.86
Nature	27.59%	4.43	2.85	Nature	20.69%	4.48	2.62

Views of students on the impact of belonging to another marginalized group on top of being a disabled person/person with a disability on the 107 (as some were taken out) indicators of four well-being composite measures

To answer research question 3, the study used 111 indicators present in the four composite well-being measures mentioned before. As the set of questions contained social groups as part of the statements, the indicators that by themselves focused on social groups were taken out, leaving 107 indicators for students to engage with. Students were asked to tick off which of the following statements they agreed with for each of the 107 indicators of the four composite measures: 1) Disabled peo-

Table 2. Students That Ticked off "No Impact" and the "Means" of Student Views on the Impact of Neurotechnologies on the Ability to Have a Good Life of Different Groups Now and in the Future

Social group/entity	Impact of neurotechnology's on the ability to have a good life in the moment		Standard deviation	Social group/entity	Impact of neurotechnology's on the ability to have a good life in the future		Standard deviation
	0 for no impact as answer	Means of the answers			0 for no impact as answer	Means of the answers	
Disabled people	2.33%	7.69	2.28	Disabled people	0.00%	8.23	2.17
The elderly	9.30%	7.07	2.71	The elderly	3.49%	7.59	2.5
Post-secondary students	13.95%	6.57	2.79	People with high income	5.81%	7.45	2.46
People with high income	16.28%	6.53	3.05	Post-secondary students	4.65%	7.43	2.42
Countries of the North	12.79%	6.47	2.64	Youth	5.81%	7.35	2.49
Youth	13.95%	6.4	2.78	Countries of the North	6.98%	7.09	2.38
Family caregiver	13.95%	6.05	2.59	Women	3.49%	7.01	2.03
Men	11.76%	6.02	2.42	Men	3.49%	7	2.1
Non-university apprenticeship students	18.60%	5.97	2.92	Nonbinary people	7.06%	6.86	2.44
Women	12.70%	5.97	2.44	Non-university apprenticeship students	6.98%	6.85	2.48
Nonbinary people	16.47%	5.91	2.66	You	9.41%	6.84	2.73
Single parents	17.65%	5.86	2.73	Family caregiver	5.81%	6.79	2.41
Countries of the South	15.12%	5.84	2.68	Single parents	6.98%	6.7	2.33
Indigenous people in Canada	16.28%	5.58	2.58	Countries of the South	8.14%	6.49	2.51
Immigrants to other countries	18.60%	5.56	2.61	Blue collar workers	8.14%	6.3	2.49
Immigrants to Canada	17.44%	5.55	2.56	Immigrants to Canada	9.30%	6.29	2.42
People of ethnic background not a majority in Canada	18.60%	5.53	2.64	People of ethnic background not a majority in Canada	9.30%	6.27	2.47
You	26.74%	5.44	3.08	Immigrants to other countries	9.30%	6.22	2.46
Blue collar workers	20.93%	5.35	2.79	Indigenous people in Canada	9.30%	6.14	2.49
People with low income	18.60%	4.97	2.54	People with low income	8.14%	5.85	2.53
Animals	36.05%	4.35	2.95	Animals	29.07%	4.71	2.95
Nature	41.86%	3.62	2.62	Nature	36.05%	3.9	2.72

ple experience a lower level of or are more impacted by the indicator than non-disabled people; 2) Disabled women experience a lower level of or are more impacted by the indicator than disabled men; 3) Disabled people from ethnic minorities experience a lower level of or are more impacted by the indicator than disabled people from non-ethnic minorities; 4) Indigenous disabled people experience a lower level of or are more impacted by the indicator than non-indigenous disabled people; 5) Disabled people from the global south experience a lower level of or are more impacted by the indicator than disabled people from the global north.

Table 3 is a summary of the full results (Supplementary Materials 9-12, www.neurores.org), showing the level of

agreement for any given statement (columns 2 to 6) for the 107 indicators. So, the number of participants who agreed with a given statement in each column (columns 2 to 6) was tallied up for each indicator. To show how many indicators received what level of agreement from students, the potential agreement (0-100% of students agreed with a given statement for a given indicator) was divided into five sections. Then for a given indicator and a given column, it was recorded how many students agreed with the column statement. For example, in Table 3, the number 21 in the row 76-100% for the Community-Based Rehabilitation Matrix and statement 1 (column 2) means that for 21 indicators of the Community-Based Rehabilitation Matrix, the agreement level for statement 1 (column 2) was between

Table 3. Views of Students on the Impact of Being a Disabled Person in General and Belonging to Another Marginalized Group on Top of Being a Disabled Person on Experiencing a Good Life as Indicated by the Indicators of Four Well-Being Composite Measures

Sentiment towards indicators % agreeing	Number of indicators				
	Disabled people experience a lower level of or are more impacted by the indicator than non-disabled people	Disabled women experience a lower level of or are more impacted by the indicator than disabled men	Disabled people from ethnic minorities experience a lower level of or are more impacted by the indicator than disabled people from non-ethnic minorities	Indigenous disabled people experience a lower level of or are more impacted by the indicator than non-indigenous disabled people	Disabled people from the global south experience a lower level of or are more impacted by the indicator than disabled people from the global north
Community-Based Rehabilitation Matrix (34 indicators)					
0%	0	0	0	0	0
1-25.99%	0	0	0	0	0
26-50.99%	0	16	0	0	0
51-75.99%	13	17	26	18	13
76-100%	21	1	8	16	21
Canadian Index of Well-being (35 indicators)					
0%	0	0	0	0	0
1-25.99%	1	3	0	0	0
26-50.99%	5	17	10	2	1
51-75.99%	5	15	25	23	12
76-100%	24	0	0	10	22
Social Determinants of Health (26 indicators, taken out the ones linked to a social group)					
0%	0	0	0	0	0
1-25.99%	0	0	0	0	0
26-50.99%	1	14	1	1	0
51-75.99%	6	12	21	18	14
76-100%	19	0	4	7	12
Better Life Index (12 indicators)					
0%	0	0	0	0	0
1-25.99%	0	0	0	0	0
26-50.99%	0	5	4	0	0
51-75.99%	5	5	6	10	7
76-100%	7	2	2	2	5

Table 4. Views of Students on the Impact of Neurotechnologies and Neuro/Cognitive Enhancements on the Indicators of Four Well-Being Composite Measures

Sentiment towards indicators % agreeing	Number of indicators					
	50 NT "yes"	50 NT "no"	50 NT "no opinion"	"Neuroenhancement*" or "neuro enhancement*" or "moral enhancement*" or "cognitive enhancement*"		
				Yes	No	Do not know/no opinion
Community-Based Rehabilitation Matrix (34 indicators)						
0%	0	0	0	0	0	0
1-25.99%	11	28	0	0	30	27
26-50.99%	21	4	33	13	4	7
51-75.99%	2	0	1	17	0	0
76-100%	0	0	0	4	0	0
Canadian Index of Well-being (35 indicators)						
0%	0	0	0	0	0	0
1-25.99%	11	25	0	4	28	19
26-50.99%	24	10	35	14	7	16
51-75.99%	0	0	0	17	0	0
76-100%	0	0	0	0	0	0
Social Determinants of Health (30 indicators)						
0%	0	0	0	0	0	0
1-25.99%	10	8	0	2	25	12
26-50.99%	20	22	30	19	5	18
51-75.99%	0	0	0	9	0	0
76-100%	0	0	0	0	0	0
Better Life Index (12 indicators)						
0%	0	0	0	0	0	0
1-25.99%	3	9	0	0	10	6
26-50.99%	9	3	12	7	2	6
51-75.99%	0	0	0	5	0	0
76-100%	0	0	0	0	0	0

50 NT: 50 neurotechnologies.

76% and 100%. Or the number 0 in the row 0% for the Community-Based Rehabilitation Matrix for statement 1 (column 2) means that no indicators generated a result where none of the students agrees with the statement.

Table 3 summarizes the number of indicators that are within the percentage agreement in each category of impact. It shows that most participants felt for most indicators that disabled people are in a more problematic situation than non-disabled people, and that if you also belong to another disadvantaged group as a disabled person, the problems often increase (being a woman versus a man with a disability was seen to have the least additional impact).

Views of students on the impact of neurotechnologies and neuro/cognitive enhancements on the 111 indicators of four well-being composite measures

To answer research question 4, students were asked for the full 111 indicators whether they think neurotechnologies and neuro/cognitive enhancements have an impact on the indicators, whereby they could answer with "yes" or "no" or "no opinion/do not know".

Summary Table 4 followed the same procedures as described for Table 3. In Table 4, the percentage of students who agreed with a given sentiment for each of the indicators was tallied up. It was looked at and recorded for a given indicator and a given column how many indicators received what percentage of agreement, and then tallied up how many indicators were agreed on for a given statement for the five levels of percentage agreement, with the range of 0-100% separated. For example, the number 11 under "50 NT yes" and Community-Based Rehabilitation Matrix and 1-25.99% row means that for 11 of the 34 indicators between 1-25.99% of the students agreed with the statement "50 NT yes". The full data are shown here (Supplementary Materials 13-16, www.neurores.org).

Table 4 summarizes the number of indicators that are within the percentage agreement in each category of impact

suggesting that more indicators were seen as being impacted than not being impacted by the neurotechnologies or neuro/cognitive enhancements. At the same time, the "do not know/no opinion" numbers were a main one for many of the indicators indicating a lack of knowledge/no opinion.

Ability concepts and neuro-abilities

Ability-related theoretical concepts [32, 38-47] developed within ability-based studies [30-37] could be used to discuss and analyze in a systematic fashion the impact of neuro-advancements and human enhancements, which include neuro/cognitive enhancements on the ability to have a good life and neuro-ability expectations contributing to neuroethics, neurotechnology governance and ability expectation governance efforts. The literature was searched for 35 ability-related concepts to see which of the concepts were used, and if yes, how much to enrich discussions around neuroenhancements and the 50 NT.

Table 5 shows that ability-based concepts including ability-based concepts used to discuss technologies were rarely or not all present, and abilit* as a term was frequently present, but the terms neuroabilit* or neuro-abilit* were not at all present, and human enhancement terms were rarely present.

Discussion

The findings of this study are discussed in two sections: one focusing on the impact of neuro-advancements on a good life, and the second focusing on neuro-advancements through ability-based studies concepts.

Neuro-advancements and the good life

The perception that neuro-advancements have the most positive impact on disabled individuals, both currently and in the future, aligns with findings from other research studies [1, 11]. One study, which interviewed neurohackers reported that "the neurohackers indicated no potential negative consequences for persons with disabilities at all though potential negative consequences and ethical dilemmas have been discussed and acknowledged in academic research" [11]; and another study investigating the views of STEM (science, technology, engineering, and mathematics) students on the effect of brain-computer interfaces on the good life showed the same positive sentiment for disabled people [1].

The students in this study were first-year undergraduate students with no exposure to neuro-advancements in their university courses so far. As such their views might reflect what they heard in the public discourse around neuro-advancements such as in the media and other non-academic literature.

Media are seen as one factor that impacts public engagement with neuro issues [133-145]. The World Health Organization demands an increase in the ability for "critical judgement of neuroscience-related material in popular media" [133]. At

the same time, the problematic coverage of disabled people in the media is described for some time [146-149], whereby the problems are twofold; one, that disabled people are simply not mentioned in the reporting of topics as potentially being impacted in a negative way [150], and the second being that a negative, medical and stereotypical imagery of disabled people is prevalent [146-150].

The problems with how media cover disabled people might be one reason for the overly optimistic view of the students on the impact of neuro-advancements on the good life of disabled people. This positive sentiment seems logical if students were only exposed to a narrative that focused on the positive use of neuro-advancements for disabled people such as within the therapeutic narrative and were not exposed to the negative aspects.

However, even as senior students with access and exposure to academic literature, the situation might not be much different, as students might not be exposed to the social implications around neurotechnologies and neuroenhancements in relation to disabled people in the academic literature either as a techno-optimistic bias is also reported for the academic literature in relation to disabled people [150]. Indeed, the findings in the here presented study are similar to the sentiment of STEM students around brain-computer interfaces and disabled reported in [1], which might reflect the reported problem that STEM students are mostly exposed to techno-optimistic narratives [151-154]. In the case of disability studies students, it might make a difference to be a senior student if a given disability studies degree engages critical with neuro-advancements, which could be done when the curriculum covers neurodiversity and Deaf culture, which are both major topics in disability studies degrees. However, although cochlear implants are often discussed in the context of Deaf culture, other neurotechnologies like brain-computer interfaces and neuro/cognitive enhancements beyond typical human abilities may not be adequately addressed in the curriculum. This oversight can limit the understanding of the broader social implications of these technologies for disabled individuals. Although techno-linked ability concepts (see next section) are increasingly used to critique techno-positivism in relation to disabled people, how much these concepts are used to teach students to critically analyze neuro-advancements through a disability rights lens is not clear. That the techno-linked ability concepts were rarely used in the academic literature focusing on neuro-advancements covered in this study (Table 5) suggests that these concepts are not used to facilitate the critical analysis of neuro-advancements in the academic literature, and as such data related to these terms might not be available to be used in classes. It also might mean that these terms are only used in classes that are taught by instructors that coined the concepts.

The good life of disabled people is impacted in many ways by neuro-advancements: 1) By non-therapeutic use of a product (consumer angle); 2) By therapeutic use of a product (patient angle); 3) By changing societal parameters caused by humans using neuro-enabled enhancement beyond the species typical (e.g., changes in ability expectations); 4) By changing societal parameters demanded and caused by neuro-enabled enhancement beyond the species typical governance and ac-

Table 5. Frequency of Ability, Human Enhancement and Technology Related Conceptual Terms Present in Online Searches of Abstracts Containing the 50 NT Terms (list see under Methods) or the Neuroenhancement Terms

Conceptual terms	The 50 NT terms listed under Methods (703,183 abstracts)	"Neuroenhancement*" or "neuro enhancement*" or "moral enhancement*" or "cognitive enhancement*" (7,077 abstracts)
35 ability-based concepts		
Abilit*	51,768	856
Neuroabilit* or neuro-abilit*	0	0
Ableism abstract/full text	11/37	0/6
"Internalized ableism"	0	0
"Ability security" or "ability insecurity" or "ableism security" or "ableism insecurity"	0	0
"Ability equity" or "ability inequity" or "ability equality" or "ability inequality" or "ableism inequity" or "ableism equity" or "ableism equality" or "ableism inequality"	0	0
"Ability privilege"	0	0
"Ability discrimination" or "ableism discrimination"	1	0
"Ability oppression" or "ableism oppression"	0	0
"Ability apartheid" or "ableism apartheid"	0	0
"Ability obsolescence" or "ableism obsolescence"	0	0
"Ability consumerism" or "ableism consumerism" or "ability commodification" or "ableism commodification"	0	0
"Ability foresight" or "ableism foresight"	0	0
"Ability governance" or "ableism governance"	0	0
Disablism (abstract and full text)	0/0	0/0
"Internalized disablism"	0	0
"Disability burnout" or "disablism burnout"	0	0
Identity	4,231	78
Identity and ableism	0	0
Identity and disablism	0	0
Six human enhancement-linked concepts		
Cyborg	76	3
Posthuman	44	2
Supercrip	0	0
Superhuman	20	0
Transhuman*	46	45
Transhuman* and ableism or disablism	0	0
Six technology-related terms		
"Assistive technolog*"	767	7
Technoableism or techno-ableism	0	0
Technodoping or techno-doping	0	0
Techno-poor	0	0
Techno-impaired	0	0
Techno disabled	0	0
Techno-supercrip	0	0
Technowashing or techno-washing	0	0

50 NT: 50 neurotechnologies.

tivism; 5) By being a potential argument used in neuro-enabled enhancement beyond the species typical governance and activism (modified from [1]).

The surveys ascertained the views of participants on the impact of belonging to the group of disabled people (Table 3, column 2) (Supplementary Materials 9-12, www.neurores.org), and disabled people also belonging to another marginalized groups (disabled women, disabled people from an ethnic minority, Indigenous disabled people, disabled people from the global south) (Table 3, columns 3 - 6) (Supplementary Materials 9-12, www.neurores.org) on the indicators of the four well-being composite measures used. Table 3 shows that over 75% of the participants felt that for 71 of the indicators, disabled people experience a lower level of or are more impacted by an indicator than non-disabled people (Table 3, column 2). Within these 71 indicators, many focus on the social situation such as employment, education, the issue of empowerment, leisure, recreation and sports, livelihood, social relationships, living standard, social norms, advocacy, discrimination, social status and stress to name a few. These indicators all can be seen to impact items 3 - 5 that influence a good life. Furthermore, the same survey showed that intersectionality is an important topic, as disabled people who belonged also to another marginalized group were seen often to be even more negatively impacted (Table 3, columns 3 - 6) (Supplementary Materials 9-12, www.neurores.org). Finally, the surveys that ascertained the views of students on the impact of neurotechnologies and neuro/cognitive enhancements on the 111 indicators of the four well-being composite measures showed that for all of them, the choice of "yes" for "impact of 50 NT terms" (list is under method), was higher than the choice of "no", and many of the indicators had a substantial number of students selecting "no opinion/do not know" as a choice. As for the impact of neuro/cognitive enhancements, the choice of "yes" was higher than for the 50 NT. The impact of neuro/cognitive enhancements choice of "no" and "yes" was on the same level for most indicators. It seems that for many indicators the "no opinion/do not know" choice decreased when the impact "yes" choice increased (Table 4) (Supplementary Materials 13-16, www.neurores.org).

At the same time, a recent study found that most of the indicators of the 111 indicators of well-being not focusing on health but social issues, which were given to the students in this study, are rarely to not at all engaged with in relation to the 50 NT and to neuro/cognitive enhancements [2]. Given the survey finding, which indicate that students saw mostly an impact or had no opinion, it suggests that an academic engagement with the social impact of neuro-advancements, not just in conjunction with disabled people but for society at large, is warranted, in order to provide evidence that can be used in courses and policy decision-making.

Neuro-advancements through an ability studies lens

In a recent study on the views of neurohackers on neuro-interventions, the following view was reported: "NT-related body modification will cause people to overcome ableism because in the future people will understand that everyone is disabled (when they have no neurotechnologies), so there will be no distinction between abled and disabled people, transforming the concept and self-concept of disability as such, both at the individual and social level" [11].

However, the sentiment voiced in that quote is flawed. This quote assumes that everyone has access to the same body ability modifications, and that therefore down the road, there will be no judgment any more based on one's ability. This is a wrong assumption. For example, in a 2006 report covering an invitational workshop on human enhancement by the American Association for the Advancement of Science (AAAS), the following drivers of human enhancement technologies were reported, which could be seen as linked to the abilities generated by human enhancements: 1) One's perceived social status; 2) One's competitive advantage; 3) Market pressures; 4) Global competitiveness; 5) Brain drain/depopulation economics; 6) National security concerns; 7) Quality of life/consumer life-style demands [155].

Considering the AAAS drivers for human ability enhancements reported, it seems more logical that we move the meaning of "health" and "non impairment" to mean one has the newest ability upgrade including neuro-ability upgrade to the body [156], whereby only a select few will be able to obtain this newest upgrade, and the ones not being able to or not wanting to will be labeled as impaired.

Then there was a study that indicated that different social groups have different ability expectations [29], which indicates the possibility of ability expectation conflicts between social groups that will lead to judging people with different abilities different.

Parents of disabled children in one study feared that one has to gain the enhancements in order to not being more marginalized [5]. There might be also the dynamic that the ones that bully disabled people will not take kindly to disabled people out-abling the bully, when the bully so far could label their disabled victim as not cutting it. A study of the views of special education teachers on brain-computer interfaces reported that they feared for their disabled students if they use visible brain-computer interfaces [157].

As neuro-ability modifications will constantly change, they will be part of the following ability timeline: emerging/eclectic (ability expectation), nice to have (ability expectation), essential to have (ableism), on the way out (ability expectation obsolescence) with the accompanying social consequences and ability judgments.

Ability privilege, the preferential access to resources and opportunities based on one's abilities [43], can lead to disparities in accessing advanced neuro-ability modifications. Those with pre-existing privileges may have earlier access to these enhancements, potentially creating a divide between the have and have not access to the enhancements. As new technologies emerge, this gap might persist, with the ability-privileged consistently having access to more advanced abilities. As such there will be all the time a distinction between the abled and disabled, and that distinction will not go away as suggested in [11]. The only change will be that the "ability creep" to improved abilities shifts the ability expectations. In the end, the scenario that everyone will be seen as impaired as in ill health if not having obtained the newest upgrade to the body/mind

[156] is more realistic than that there will be no abled and disabled labels anymore.

The body/mind is the ultimate target for ability consumerism, and this comes with consequences.

The "concepts of 'techno-poor disabled' (being discriminated because one cannot or does not want to upgrade beyond the species-typical (could also be called techno-disablism)), 'techno-poor impaired' (seeing oneself and/or being seen by other as ability impaired due to not having the latest upgrade to the body/mind), and 'techno-ableism' (a rhetoric of disability that at once talks about empowering disabled people through technologies while at the same time reinforcing ableist tropes about what body-minds are good)" (quote from [158], for techno poor disabled and techno poor impaired see [32], for techno-ableism see [45, 46]) are all applicable and are more realistic in what they see as the consequence than the notion that we will not have the distinction between abled and disabled any more, as the quote in the study [11] suggests.

Many will internalize the judgment of a given new ability to be essential, which is indeed one prerequisite for ability consumerism to work. And by aiming for these abilities, one might also internalize disablism so seeing the negative treatment of the ones lacking these abilities as normal. To give one example from history, women were labeled by men as missing the "essential" ability of rationality, and men therefore used this set up to disable women for example by denying them the right to vote [31, 159]. Many women internalized the need for rationality and that women are not rational (one could call internalized ableism [38], as one internalizes ability judgments), but also internalized the disabling use of such judgment that women cannot vote (one could call internalized disablism that one internalizes the disabling use of ability judgments as just and right [39-42],) and with that opposed women rights to vote, as this was seen as an ability women should and could not strive for [160, 161].

Ability security is the ability to feel one can have a decent life with one's set of abilities [32]. If certain abilities become obsolete (ability obsolescence) and one cannot compete in the job market without upgraded abilities, this ability insecurity (not feeling one has a chance for a decent life with one's abilities) [32] will fuel that one will go for ability upgrades. Indeed, drivers for human enhancements such as "social status", "being competitive" or "quality of life/consumer life-style demands" the AAAS report identified [155] can be seen to reflect the fear of ability insecurity and to be a cause of ability insecurity. In the same way, disabled people who feel that their existing ability (seen by others as impaired abilities) is not allowing them to have a decent life might go for anything that promises them a "fix", so they can get employed, have an income, and experience other aspects of a good life.

Ability identity security is that one can be at ease identity wise with one's set of abilities [32]. Disabled people that do not adhere to a negative, deficiency, impairment view of oneself such as disabled people adhering to the neurodiverse or Deaf culture identity cannot experience ability identity security because they are forced to accept the deficiency label, which is the default in many discussions and narrative. Ability identity insecurity is one reason why many disabled people do not disclose their identity (e.g., autistic camouflaging [162-166]). Furthermore, if one constantly hears that one is defec-

tive, many will internalize this negative view. If one constantly experiences systematic discrimination due to one's set of abilities, many will experience what is called "disablism burnout" as in "emotional despair engendered by thwarted opportunities and blocked goals. It is aggravated and intensified by years of exposure to disability prejudice and devaluation" [167]. All of this will push disabled people to modify themselves to become ability normative, so they are accepted for who they are.

Conclusions

Well-being is essential for the ability to have a good life [1] and has many social determinants [2]. Neuro-advancements are recognized to raise many social issues [3-12] and with that impact the good life on many levels. Neuroethics and neurotechnology governance discourses emerged to decrease or prevent the negative impact of neuro-advancements [3, 4, 11, 13, 14]. Disabled people are one of the main user targets for neuro-interventions [18-22, 64-67], and what counts as a neuro-impairment constantly shifts [68-71].

This study provides evidence that participants felt that human enhancements, which included neuro/cognitive enhancements, and neurotechnologies had an impact on all the social groups they could choose from, whereby disabled people were seen to be impacted the most positively with the trend increasing from in the moment to the future. Most students also agreed for most well-being indicators with the answer choice that disabled people are in a more problematic situation than non-disabled people, and that the problem is even worse if disabled people also belong to another disadvantaged group. For the well-being indicators being impacted by neurotechnologies or neuro/cognitive enhancements, the choice of being impacted was chosen slightly more than not being impacted. At the same time, the "do not know/no opinion" numbers were substantial indicating a lack of knowledge, whereby the "do not know" was in general higher for the neurotechnologies than neuro/cognitive enhancements, which reflects that they read more about neuro/cognitive enhancements other than neurotechnologies. The hit counts obtained from the literature review indicate that ability-based concepts were rarely or not at all employed to discuss neurotechnologies or neuro/cognitive enhancements.

Given the findings, various research studies could be done as follow-up studies. For example, one could use other composite measures beyond the ones used in this study such as the "disability and well-being monitoring framework and indicators" [168], the satisfaction with life scale [169, 170], the perceived life satisfaction scale [171, 172], and the capability approach [102-108], to just name four.

Buchman et al argued that neuroethics should engage "more with theories of social justice, particularly how neurotechnologies might affect already unequal societies" [173]. This study contributes to this analysis by recording the views of one group of participants on what the impact of neuro-advancements on the ability to a good life might be. The results of the study suggest that intersectionality between disability and other marginalized characteristics is an important aspect to

think about around the impact of neuro-advancements on well-being indicators. The techno-optimistic view of the students around the impact of neuro-advancements on disabled people, as reflected by the means number of the survey, suggests that it might be warranted to investigate further the impact of media and academic coverage of neuro-advancements on the perception of neuro-advancements. Questions could be given to the students as to why they believed that the neurotechnologies would have such a positive impact on disabled people. The techno-optimistic view found in relation to disabled people in this study might be partly due to the media influence on the public engagement with neuro issues [133-145]. The study suggests that students might need access to more diverse data, and that data which cover the societal impacts, including potential problems of neuro-advancements in general, and in relation to disabled people, must be more visible. The study data also suggest that the techno-optimistic bias is not only a problem for STEM education [151-154], but also for disability studies education and neuro-education.

The World Health Organization demands an increase in the ability for "critical judgement of neuroscience-related material in popular media" [133]. This is needed also for the students in this study, given the techno-optimistic view but also given the high percent of "do not know/no opinion", which suggests that students were up to then not be exposed enough to the topic. The ability-based concepts could be one tool to perform a critical analysis.

One could perform the same surveys with other student groups within disability studies, such as other disability studies programs and older students in disability studies degrees. One could also give surveys to students involved in neuro-based degrees and degrees that train people that develop many neurotechnologies. Within these groups, one could ask more specifically whether the impact of neuro-advancements might be good or bad for the individual well-being measures as one could expect participants to have been exposed to and be more knowledgeable on neuro-advancements than disability studies students. And one could conduct interviews instead of surveys to better understand participants' answers like why they answered the impact on the good life in certain ways for certain groups. One could also extend the scope of the study we did by asking students about the utility of the surveys in general and about using the answers as part of the lectures.

A lot has been written about the need to govern neuro-advancements [3, 15-17], but one also needs to govern ability expectations [174], especially in relation to neuro/cognitive enhancements as the neurohacker study [11] showed. Using the ability-based theoretical concepts allows for a seamless expansion to engage with a vision, which moves the ability expectations of the body beyond the species-typical and neuro-ability consumerism in general. The concepts also allow for the analysis of why some disabled people feel forced to obtain normative neuro-ability. The ability-focused concepts are uniquely situated and ideal to discuss ability-based expectations, judgments, norms, and conflicts in all settings, including the beyond species-typical ones and with that to engage with the ability expectation creep to ever increasing abilities linked to a transhuman and posthuman visions.

To leave the reader with a quote from a dialogue between the two main characters in the 2003 computer game "Deus Ex Invisible Wars", a game that focused on the future with humans that were enhanced, highlighting the foundational impact of ability judgments and ability consumerism on society.

"Paul Denton: If you want to even out the social order, you have to change the nature of power itself. Right? And what creates power? Wealth, physical strength, legislation - maybe - but none of those is the root principle of power.

Alex D: I am listening.

Paul Denton: Ability is the ideal that drives the modern state. It is a synonym for one's worth, one's social reach, one's 'election', in the Biblical sense, and it is the ideal that needs to be changed if people are to begin living as equals.

Alex D: And you think you can equalize humanity with biomodification?

Paul Denton: The commodification of ability - tuition, of course, but increasingly, genetic treatments, cybernetic protocols, now BIOMODS - has had the side effect of creating a self-perpetuating aristocracy in all advanced societies. When ability becomes a public resource, what will distinguish people will be what they do with it. Intention. Dedication. Integrity. The qualities we would choose as the bedrock of the social order" [175].

Supplementary Material

Suppl 1. The impact of human enhancement beyond species-typical on the ability to have a good life in the moment on the groups indicated. 0: being not impacted; 1: being purely negative; 2 - 4: being more negative than positive; 5: being equal positive and negative; 6 - 9: being mostly positive; 10: being purely positive impact.

Suppl 2. Statistical numbers obtained for Supplementary Material 1 organized also from high to low based on means.

Suppl 3. The impact of human enhancement beyond species-typical on the ability to have a good life in the future on the groups indicated. 0: being not impacted; 1: being purely negative; 2 - 4: being more negative than positive; 5: being equal positive and negative; 6 - 9: being mostly positive; 10: being purely positive impact.

Suppl 4. Statistical numbers obtained for Supplementary Material 3 organized also from high to low based on means.

Suppl 5. How do you see neurotechnologies, for example brain computer interfaces' impacting ability to have a good life in the moment? 0 = no impact; 1 = purely negative impact; 2 - 4 = more negative impact; 5 = equal negative and positive impact; 6 - 9 = more positive impact; 10 = only positive impact.

Suppl 6. Statistical numbers obtained for Supplementary Material 5 organized also from high to low based on means.

Suppl 7. How do you see neurotechnologies, for example brain computer interfaces' impacting ability to have a good life in the future? 0 = no impact; 1 = purely negative impact; 2 - 4: more negative impact; 5 = equal negative and positive impact; 6 - 9 = more positive impact; 10 = only positive impact.

Suppl 8. Statistical numbers obtained for Supplementary Material 7 organized also from high to low based on means.

Suppl 9. Community-Based Rehabilitation Matrix indicators (please click on each of the statements you agree with for each of the indicators).

Suppl 10. Canadian Index of Well-being indicators (please click on each of the statements you agree with for each of the indicators).

Suppl 11. OECD Better Life Index indicators (please click on each of the statements you agree with for each of the indicators).

Suppl 12. Social Determinants of Health indicators (please click on each of the statements you agree with for each of the indicators).

Suppl 13. Do you think there is an impact of the listed items on the Community-Based Rehabilitation Matrix indicators?

Suppl 14. Do you think there is an impact of the listed items on the Canadian Index of Well-being indicators?

Suppl 15. Do you think there is an impact of the listed items on the OECD Better Life Index indicators?

Suppl 16. Do you think there is an impact of the listed items on the Social Determinants of Health indicators?

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Conflict of Interest

The author declares no conflict of interest.

Informed Consent

Informed consent was obtained.

Author Contributions

Sole author so everything done by the author.

Data Availability

The author declares that data supporting the findings of this study are available within the article.

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