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NATŪRALAUS VARTOTOJO POTYRIO ĮTAKOS PRIKLAUSOMYBĖ NUO INFORMACIJOS PASKIRSTYMO DĖSNINGUMŲ

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Santrauka. Darbe apžvelgiami pagrindiniai natūralaus vartotojo potyrio kūrimo metodai ir dėsniai: Fitso dėsnis, Hiko dėsnis, valdymo dėsnis, Gestalto dėsniai, artumo dėsnis, panašumo dėsnis, uždarymo dėsnis, tęsimo dėsnis, iliustracijos ir pagrindo dėsnis, paprastumo dėsnis, simetrijos dėsnis, patirties dėsnis. Parodoma, kaip dėsniai leidžia priartinti vartotoją prie kūrėjui norimo pasiekti rezultato. Norint pasiekti efektyvų rezultatą būtina atsižvelgti į skirtingose situacijose veikiančius skirtingus dėsnius. Neteisingai taikomi dėsniai gali turėti neigiamą poveikį.

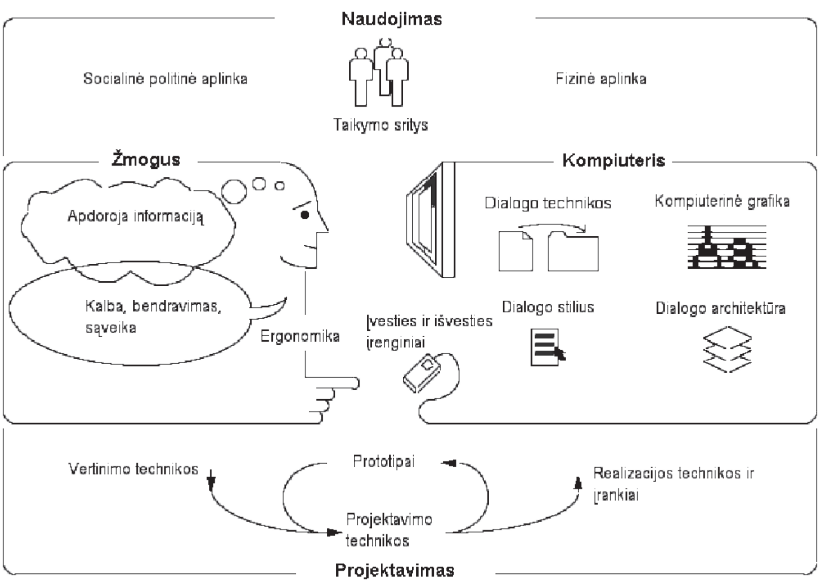
Reikšminiai žodžiai: žmogaus ir kompiuterio sąsaja, natūralus vartotojo potyris, natūralaus vartotojo potyrio kūrimo metodai.

Įvadas

Kadangi žmogaus veikla susijusi su išmaniaisiais telefonais, planšetiniais kompiuteriais ir sistemomis, pagrįstomis interneto (ang. *Web*) technologijomis, nejuntamai tampama patyrusiu naudotoju: tie patys principai taikomi naudojant programas, intuityviai elgiamasi su jautriu judesiui ekranu ar nesąmoningai lyg loginės sąsajos suvokiamas informacijos grupavimas. Net jaučiamasi laimingu tai darant! Ne, tai ne įprotis ir ne savaiminės emocijos, tai sudėtingas analitikų, tyrėjų, metodininkų, dizainerių, programuotojų darbas. Žmogaus ir kompiuterio sąveikos (toliau ŽKS) (angl. *Human Computer Interaction*) išmanymas šiandien yra tiesioginis žingsnis į sėkmingą produktą, tačiau kaip tai pasiekti, tiria plati ir gana sudėtinga natūralaus vartotojo potyrio (angl. *Natural User Interface – NUI*) mokslo sritis.

ŽKS yra informatikos, psichologijos, sociologijos, projektavimo ir dar daugelio kitų dalykų sandūroje. Žmogus yra sudėtingas organizmas, o kompiuteris – sudėtinga sistema, todėl ir jų sąveika taip pat yra sudėtinga (1 pav.).

ŽKS tikslas – suprasti, kaip vartotojai atlieka veiksmus, kokias užduotis jiems reikia atlikti ir kaip kompiuterinė sistema gali palengvinti užduočių atlikimą – padaryti jį efektyvesnį ir patogesnį. Suprasti vartotoją, vadinasi,



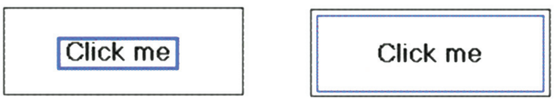
1 pav. Žmogaus ir kompiuterio sąveikos kontekstas
Fig. 1. Man computer interaction

suprasti jo gebėjimus, įgūdžius, pomėgius ir pan., įskaitant atmintį, regėjimą, klausą, pažinimo ar judesių įgūdžius. Reikia suprasti ir tai, kaip kompiuterinė sistema gali padėti vartotojui ir koks yra geriausias jos sąsajos su žmogumi būdas. Reikia žinoti vartotojo užduotis, jų ryšius su kitomis užduotimis ir geriausius atlikimo būdus naudojant kompiuterinę sistemą. Reikalingos žinios apie žmogaus darbo aplinką (kultūrinę, geografinę, socialinę) (Moroz-Lapin 2008).

Nagrinėjant ŽKS, visi duomenys skirstomi į dvi sritis: informacijos apie žmogų surinkimą (konkrečios tikslinės grupės vartojimo įpročiai ir poreikiai) ir informacijos panaudojimą prieš jį patį (atitinkama informacija pateikiama reikiamoje vietoje tikslingai pagal jau sudarytą tikslinį vartotojo (žmogaus) apibūdinimą). Darbe analizuojami antrosios dalies teoriniai modeliai (Schelkes 2003). Šie modeliai remiasi dėsniais ir jų variacijomis, kurie jau daugelį metų taikomi psichologijoje, kai kurie – net dešimtmečius. Jie padeda suprasti žmonių protą, pasirinkimus, mąstyseną, elgseną. Dėsnių taikymas informatikoje palengvina sąsajos projektavimą ir padeda ją padaryti palankesnę, malonesnę naudotojui, jie suteikia papildomų duomenų, kuriais remiantis galima priimti tam tikrus sprendimus.

Fitso ir Hiko dėsniai

Fitso dėsnis (angl. *Fitts's law*) žmogaus ir kompiuterio sąveikos bei ergonomikos modelis. Pagal šį dėsnį greito ir tikslaus judesio atlikimo trukmė priklauso nuo taikinio dydžio ir atstumo iki jo (2 pav.): kuo toliau žmogus pelės kursorių turi nuvesti objektu, tuo daugiau pastangų jis įdės. Kuo mažesnis objektas, tuo sunkiau bus ant jo paspausti. Tai reiškia, kad lengviausiai pastebimi ir lengviausiai paspaudžiami yra tie objektai, kurie yra arčiausiai nuo dabartinės žymeklio padėties ir turi daug tikslinės erdvės. Blogiausiu įmanomu objektu yra laikomas toks, kuris yra labiausiai nutolęs nuo dabartinės žymeklio padėties ir yra labai mažo dydžio. Kūrėjai linkę daryti įrankių juostas ekrano viršuje, apačioje ir šonuose dėl nenatūralių ribų sukurtų vaizduoklio kraštų. Pagal Fitso dėsnį ant šių taikinių žymeklis bus uždedamas begalybę kartų, nes jų tiesiog neįmanoma nepastebėti. Pagal šį dėsnį jiems reikia suteikti daug tikslinės erdvės.



2 pav. Linija aplink užrašą rodo spaudžiamos srities ribas

Fig. 2. The line around the label shows the boundaries of the clickable area

Linija aplink užrašą rodo tą mygtuko sritį, ant kurios galima paspausti. Kairėje (2 pav.) pavaizduotas sprendimas reikalauja spausti labai mažą mygtuko srities dalį. Didžioji dalis mygtuko erdvės lieka nepanaudota, nes tik aplink tekstą esanti sritis yra aktyvi. Kuo toliau pelės žymeklį reikia perkelti, norint patekti į spaudžiamą mygtuko sritį, tuo lengviau padaryti klaidą. Tam tikrais atvejais tik pats užrašas gali būti spaudžiamas, kuris gali būti labai mažas, priklausomai nuo naudojamo šrifto dydžio. Dešinėje (2 pav.) pavaizduotas sprendimas leidžia naudoti visą mygtuko sritį, todėl į ją yra daug lengviau pataikyti.

Hiko dėsnis (angl. *Hick-Hyman Law*). Laikas, reikalingas priimti sprendimą, ilgėja, kai galimų pasirinkimų skaičius didėja. Hiko dėsnis teigia, kad laikas, reikalingas priimti sprendimą, priklauso nuo galimų pasirinkimų skaičiaus. Pavyzdžiui, kai lėktuvo pilotas turi reaguoti į kokį nors įvykį, tarkime, nuspausti pavojaus mygtuką, Hiko dėsnis spėja, kad kuo daugiau alternatyvių mygtukų bus, tuo ilgiau pilotas užtruks priimdamas sprendimą prieš nuspausdamas reikiamą mygtuką. Kompleksinis uždavinys, reikalaujantis sakinių skaitymo ir intensyvios koncentracijos, esant trims variantams, paprastai gali būti sprendžiamas ilgiau nei paprastas postūmio ir atsako uždavinys, esant šešiems variantams. Hiko dėsnis yra labiausiai taikytinas paprastoms užduotims spręsti, kuriose yra unikalus atsakymas į kiekvieną postūmį. Pavyzdžiui, jei nutinka įvykis A, tada spauskite 1 mygtuką, jei – įvykis B, spauskite 2 mygtuką. Dėsnis vis mažiau taikomas, kai didėja uždavinio sudėtingumas (Schelkes 2003).

Valdymo dėsnis ir Gestalto dėsniai

Valdymo dėsnis (angl. *Accot-Zhai steering law* arba *Accot's law*). Šis dėsnis – tai prognozavimo modelis, kaip greitai galima naršyti ar judėti dviejų matmenų tunelyje. Tunelį galime suvokti kaip kelią ar trajektoriją plokštumoje, kuri turi tam tikrą storį arba plotį ir plotis gali keistis. Valdymo dėsnio tikslas – nuo vieno tunelio galo iki kito pereiti taip greitai, kaip tik įmanoma, neliečiant jo kraštų (interneto svetainėje tai būtų pirkimo procesas nuo vartotojo atėjimo į svetainę iki prekės ar paslaugos įsigijimo) (Faulkner 2003). Taip pat valdymo dėsnis prognozuoja momentinį greitį, kuriuo galima judėti tuneliu, ir bendrą laiką, reikalingą pereiti visą tunelį. Šiame kontekste valdymo dėsnis yra žmonių judesių prognozavimo modelis, susijęs su greičiu ir bendru laiku, kuriuo naudotojas dviejų matmenų tunelyje, pateiktame ekrane, gali valdyti žymeklį, stengdamasis kuo greičiau nukeliauti iš vieno tunelio galo į kitą ir neišeiti už tunelio ribų.

Gestalto dėsniai (angl. *Gestalt Laws*) yra pagrindiniai principai, kaip skirtingi elementai gali būti suvokiami, kai jie sujungiami tam tikru būdu ar eiliškumu. Gestalto dėsniai gali padėti sukurti struktūrą ir vieningumo pojūtį žiniatinklio svetainėje ar naudotojo sąsajoje. Jais remiantis galima patraukti vartotojo dėmesį prie tam tikro elemento ar jų grupės, kurie yra svarbūs, taip pat sukurti balanso ir stabilumo pojūtį. Gestalto dėsniai yra iš psichologijos srities, pirmą kartą jie buvo pristatyti XX amžiuje. Šie dėsniai iš esmės yra tai, kaip elementai suvokiami ir sujungiami į vieną visumą. Juos būtina išmanyti kuriant sistemas vartotojams.

Artumo ir panašumo dėsniai

Artumo dėsnis (angl. *Law of Proximity*) rodo, kad elementai, kurie yra arti vienas kito, dažnai suprantami kaip vienas vienetas, visuma. Artumo dėsnis taikomas norint rodyti žiniatinklio tinklalapyje dvi elementų kategorijas, iš kurių kiekviena turi daugiau kaip vieną turinio dalį. Sugrupuotos vienos kategorijos dalys dedamos arčiau viena kitos (naudojama *Google*, *Youtube*) (Dix *et al.* 2004).

Panašumo dėsnis (angl. *Law of Similarity*) tvirtina, kad elementai, kurie atrodo panašūs, suvokiami kaip vienas vienetas. Taigi elementai, kurie turi tą pačią spalvą, formą ar kitas bendras savybes, suvokiami kaip priklausantys vienai kategorijai. Šis reiškinys gali būti labai naudingas elementams grupuoti (naudojamas *Gmail*, *Amazon*).

Uždarymo ir tęsimo dėsniai

Uždarymo dėsnis (angl. *Law of Closure*) aiškina, kodėl elementai atpažįstami, net jei jie yra neužbaigti (Faulkner 2003). Taip yra dėl jau žmogaus turimos ankstesnės patirties ir ankstesnių žinių apie galimas formas ir skaičius, nes tokiu būdu žmogaus protas užpildo trūkstamas elemento dalis. Kai yra baltas fonas su apvaliais kampais (3 pav.), kuris tęsiasi iki puslapio apačios, mums neatrodo, kad puslapis tuo ir baigiasi, mes įsivaizduojame, kad turinys tęsiasi.

3 pav. Uždarymo dėsnis (http://www.apple.com/)

Fig. 3. The law of closure (http://www.apple.com/)

Tęsimo dėsnis (angl. *Law of Good Continuation* arba *Law of Continuity*) taikomas tiek projektavimo, tiek turinio elementų prasme. Akys gali lengvai ir natūraliai sekti elementus, išdėstytus palei testinę liniją, ir tie elementai bus suvokiami kaip vienetas. Be to, elementai, kurie eina vienas po kito, suvokiami kaip vienas vienetas. *Concept7* svetainė taiko „gero tęsimo“ dėsnį, maža rodykle, esančia puslapio dešinėje pusėje, nukreipdama naudotojų žvilgsnį (Interface... 2011).

Iliustracijos ir pagrindo dėsnis

Iliustracijos ir pagrindo dėsnis (angl. *Law of Figure and Ground*) apibūdina, kaip žmogus supranta objektą (paveikslėlį ar kitą figūrą), priklausomai nuo priekinio ir galinio plano. Jeigu priekinis planas yra ryškus, o galinis tolygus, niekuo neišsiskiriantis, tai objekto forma pirmiausia suprantama žiūrint į priekinį planą, bet tame pačiame paveiksle kitas objektas gali būti atpažintas kaip sudarytas iš galinio plano, taigi, priekinis planas yra kaip fonas. Dėsnis dažnai taikomas logotipams projektuoti.

Paprastumo ir simetrijos dėsniai

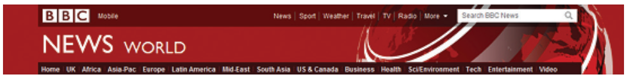
Paprastumo dėsnis (angl. *Law of Simplicity*) nurodo, kad elementai visada suvokiami lengviausiu galimu būdu. Apskritai paprastumas pabrėžia ypatybių svarbą. Tai gali būti kaip žiniatinklio svetainės pranašumas. Atsižvelkite į tai, kas paprasta, ir sutelkite dėmesį į tai, kas iš tikrųjų svarbu. 4 pav. parodytas pavyzdys iš svetainės: paprastumas ir grynumas kiek tik įmanoma.

Simetrijos dėsnis (angl. *Law of Symetry*). Šis dėsnis apima faktą, kad pirmenybė teikiama ne asimetriniams, bet simetriniams objektams. Simetriniai objektai asocijuojasi su teigiamais aspektais, tokiais kaip stabilumas, pastovumas ir struktūra, o asimetriniai sudaro gana neigiamą įspūdį, kad kažkas vyksta neteisingai, kai ko trūksta ar nėra balanso. Žinoma, žiniatinklio svetainė gali niekada nebūti visiškai simetriška, bet galima atkreipti dėmesį į suprastą simetri-

4 pav. Paprastumo dėsnis (http://mozilla.org)

Fig. 4. The law of simplicity (http://mozilla.org)

ją. Taigi, simetrija nebūtinai turi būti sukurta pagal turinį ir taip pat pagal estetinius elementus, tokius kaip spalva ar projektavimo elementai. Pavyzdžiui, BBC žiniatinklio svetainės projektuotojas antrame plane naudoja abstraktų žemės rutulio paveikslą, kad sukurtų harmoningą ir subalansuotą išvaizdą (5 pav.).



5 pav. Simetrijos dėsnis (http://www.bbc.co.uk)
Fig. 5. The law of symmetry (http://www.bbc.co.uk)

Patirties dėsnis

Patirties dėsnis (angl. *Law of Experience*). Kitas Gestalt dėsnis aiškina, kad galime tikėtis, jog žmonės panaudos ankstesnes žinias, kad suprastų tam tikrus elementus. Bendras pavyzdys yra susijęs su gramatika ir rašyba. Pavyzdžiui, kartais rašybos klaidos yra nepastebimos todėl, kad žodis įsimenamas apskritai ir nežiūrima į kiekvieną raidę (Moroz-Lapin 2008).

Kuriant natūralų vartotojo pojūtį, dėsnių yra kur kas daugiau, tačiau ne vien dėsniais kuriamos sistemos. Taip pat reikalingi tyrimai architektūriniu požiūriu, kultūriniu aspektu (europietiškas, amerikietiškas, ukrainietiškas, kinietiškas stilius), kuris tampa ypač aktualus naudojant tarptautinius projektus. Kai kurie dėsniai yra unikalūs, kiti iš dalies sutampa vienas su kitu, kai kurie yra naudingesni žiniatinklio svetainės ar naudotojo sąsajai projektuoti, kiti mažiau, vienus galima lengvai pritaikyti, kitus – sudėtingiau. Apskritai galima daryti išvadą, kad ŽKS dėsniai yra pagrindas, kurį teisingai sukonstravus toliau galės dirbti kiti specialistai (architektai, dizaineriai, rinkodaros specialistai, pardavėjai), o tyrėjai ir analitikai tirs naujus dar tik besiformuojančius dėsnius ir ieškos jiems tinkamų pritaikymo metodikų.

Išvados

1. Dėsniai leidžia priartinti vartotoją prie kūrėjui norimo pasiekti rezultato, tačiau reikia atsižvelgti į skirtingose situacijose veikiančius skirtingus dėsnius. Neteisingai taikomi dėsniai gali daryti neigiamą poveikį.
2. Taikant dėsnius reikalingos jų efektyvumą pagrindžiančios metodikos, kurios pagal atitinkamus parametrus pateiktų gaunamus natūralaus vartotojo potyrio efektyvumo rodiklius.

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THE INFLUENCE OF NATURAL USER EXPERIENCE ON INFORMATION LAWS

E. Švedaitė

Abstract

This article reviews the main cause of user experience on development methods and laws, including Fitt's Law, Hick-Hyman Law, Accot's Law, Gestalt Law, proximity, similarity, closure, continuity, figure and ground, simplicity, symmetry and experience.

Keywords: human computer interaction, natural user interface.

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Electroencephalography and Eye Gaze Movement Signals' Usage for Estimation of User Interface Usability

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***Abstract*—Task execution time is one of components used to estimate system's usability. Since information search is one of the most important tasks in any computer system, the eye movement should be taken into account while designing system's interface. Fitts' law allows to estimate probable eye movement time based on the distance between objects and their size. User's motivation can significantly influence the eye movement speed. In this paper we analyse experimentally how Fitts' law parameter (slope) changes when user is motivated and when there is less motivation to execute the task. Our experiments confirm that gamma brainwave activity can be used as a metric to estimate the motivation level. This allows a more objective estimation of the motivation level as compared to situation when motivation level is estimated by an expert's observation. It is also demonstrated that the slope in Fitts' law is up to five times smaller when children of age two to four years are motivated to reach the object and the motivation can be raised by presenting new, unseen objects. Obtained results allow a more precise estimation of the eye movement task execution time as well as provide additional insights for system interface designers aiming to attract small children.**

***Index Terms*—Brainwave activity, eye gaze, Fitts' law, motivation.**

I. Introduction

The design of system usability is a very complicated, multidimensional task. According to J. Nielsen [1] system usability aims to identify problematic places rather than to find universal rules for perfect system design. This is highlighted by other authors [2]–[8]. In these papers ergonomic properties of various systems are analysed and specific recommendations provided. It is pointed out that the usability is strongly dependent on user's properties as well. In the standard of the International Organization for Standardization and the International Electro technical Commission ISO/IEC 9126-1, 2001 [9], software quality is divided into seven main categories with one called "Quality in Use" as described in part 4 [10] and depending on the system's user properties.

One of metrics in this standard is Task time (*Ta*) - how long does it take to complete a task. Task type and complexity can vary depending of the type of the system; however the most common task in an information system is to find some information or even to notice some information on the user interface (UI). It takes time to move the eye gaze from one point in the UI to another and just then certain actions are done to finish the task. The eye gaze movement as a usability characteristic is important as current tendencies implies the eye movement can be used as input device instead of mouse or other device [11]–[13]. Therefore eye gaze movement could be used for complex UI task execution rather than visual search only.

Fitts' law was published on 1954 in paper "The information capacity of the human motor system in controlling the amplitude of movement" [14] and revealed how the speed and accuracy of muscle movement depends on each other. The author presented the idea that the movement is not straight to the centre of the target: first of all there is a jump close to the object (see Fig. 1) with some circle of error for the first try and then it is corrected with a smaller circle of error for the second try until the target is reached.

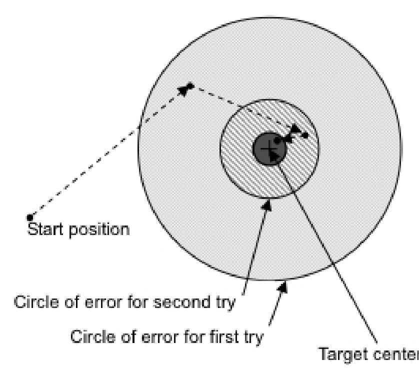

Fig. 1. Step-wise movement towards target [12].

Despite the fact that Fitts did not present a formula by himself, his idea was formalized by other authors [15] and is presented in (1)

$$t = a + b \times \log_2(ID), \quad (1)$$

where t is the mean time to hit the centre of a target and

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constants *a* and *b* are estimated from a particular experiment. Constant *a* is called the no informational part or reaction time. Constant *b* is the informational part in seconds per bit or a slope. There distance from start point to the centre of the target is called amplitude *A* while the tolerance of the jump is called width *W* (radius or width of the target). *ID* is the index of difficulty

$$ID = \frac{2 \times A}{W}. \quad (2)$$

There were multiple experiments with Fitts' law, when it was adapted to different Human Computer Interaction (HCI) devices [16]–[22]. Depending on the used HCI the slope parameter is different; however Fitts' law can be applied to most of them. This also is important in task execution time calculation as we can define how long the user will need to see the object as well as how long it will take to reach the object, using different HCI devices, as while the object is not reached usually any actions can be done with it.

To get the task execution time we can divide certain task into small steps and with the help of Fitts' law to calculate how long it will take for the user to get from one place in the UI to another (by seeing it or by reaching it with some other HCI device). The movement time together with additional time needed to execute certain activity after the object is reached can help to identify the task execution time with more precision. As well it can be used to analyse UI layout efficiently in a sense of task execution time (to identify which layout is more appropriate for a certain task execution, when the most important criteria is task execution time).

Even though existing discussions on whether the Fitts' law is suitable for eye movement [23] and limitations of Fitts' law to achieve accurate results when ID is close to zero [24], [25], this law is still actually used in system usability testing and the only usability related quantitative law proved by experiments. However there are just a few papers on how Fitts' law parameter is related to user's properties (usually medical condition and no published papers on estimation of motivation level to the user, its eye movement slope value *b*) [26]–[28].

By grooving up the motivation can be trained even to an unconscious level. It means when an adult gets some task a certain level of motivation automatically exists in the execution of the task [29]. However it does not mean all adults are motivated all the time. Usually there are situations when persons are using different applications with no reason, to spend some time only or do automatic actions as UI is known very well for him. Meanwhile during usability test adults get a certain task and most of them are willing to finish it as quick as possible. Automatic prejudice comes into play, when after giving some task to the user he or she might guess the purpose of the task and unconsciously starts acting differently comparing to normal work with the system. All these reasons must be taken into account in order to execute a clear experiment to identify the impact of motivation level to the slope of eye gaze movement.

One of way to monitor a person's emotions is to analyse electroencephalography (EEG) signals. During the last few years more brainwave research devices appeared [30]. This allowed investigating user's emotional properties, brainwave activity, to use EEG in HCI [31]–[33]. The analysis of brainwave is not a simple task as different types of brainwaves exists [34] (see Table II) and it is still a discussion how to interpret these signals correctly. Previous researches found delta waves are primarily associated with deep sleep and the waking stage. As the signal frequency is very low sometimes it might be confused with signals of bigger muscles of the neck or jaw. Theta waves usually indicate emotional discomforts such as stress, frustration, disappointment as well as creative inspiration or deep meditation. Alpha waves are indicating a relaxed awareness and inattention, while beta waves usually associated with active thinking, active attention, and focus on the outside world or solving concrete problems. Comparing these to brainwaves alpha indicates a mindless state rather than a passive one, and can be reduced or eliminated by hearing unfamiliar sounds, anxiety or mental concentration. Gamma waves have the biggest frequency. Its activity is related to subjective awareness, attention.

TABLE I. BRAINWAVE TYPES, FREQUENCY RANGES AND ASSOCIATIONS WITH DIFFERENT PROPERTIES, ACTIVITIES [34].

Brainwave type	**Rate of change, Hz**	**Association with**
Delta	0,5–4	Deep sleep, waking state.
Theta	4–7	Unconscious material, creative inspiration and deep meditation.
Alpha	8–13	Sublime, flying, floating, lightness, peace, and tranquility.
Beta	13–30	Active thinking, active attention, focus on the outside world or solving concrete problems.
Gamma	>35	Consciousness.

Some brainwave association is still discussed as there are many different arguments to what these waves could mean, how it could be caused, how different combinations of brainwave activity should be interpreted. One of ideas is that beta and gamma waves usually are associated with attention while the combination of both of them is correlated to focused attention [35]. This means EEG and betas as well as gamma brainwave analysis can be a suitable tool to identify is the child motivated during some task or no, as his or her brain activity might say more on this question comparing the child.

The aim of this work is to analyse how the slope parameter changes in Fitts' law when different user's motivation level exists. This will provide data whether the user's motivation influences the eye gaze movement speed, depending on whether is he or she motivated or not. This analysis will be on answering two research questions:

1. How to measure person's motivation level or its changes?
2. Does the motivation level influences the eye gaze movement speed and should motivation level be taken into account for eye gaze movement time prediction in Fitts law?

By defining the difference between motivated and less motivated users, system UI designers will be able to define the expected task execution time even more precisely, taking into account the motivation level of the user. While motivation level estimation process will allow gathering data on slope value range in different motivation levels.

II. EXPERIMENT METHODOLOGY

In this work we chose to analyse small children from ages 2 to 4. Children of this age are capable to choose freely and have minimal level of prejudice [36]. This allows us to get a real expression to different UI rather than impact of addiction to some kind of UI. In addition small children are easier to motivate for short time period [29] therefore it is easier to achieve significant change in motivation levels during the experiment. However when using children in this of experiment rather than adults it is difficult to ask the child how motivated they were during a certain task - the dictionary of children is not enough to express his or her emotions, children might not be aware of the term motivation, how to compare it etc. Therefore additional methods for motivation level estimation have to be used.

To investigate the impact of motivation on eye gaze movement slope we recruited fourteen participants, as recommended by Microsoft for usability testing experience with children [36]. All of them were children from 2 to 4 years old. Current research states children in this age group are too young to clearly express their satisfaction levels [37]. Therefore there are no unified methods to test system usability with this age group. All of them participated in this experiment with one of his or her parents. Parents did not participate in the experiment but were used to keep the child calm and relaxed. Before the experiment started, all parents had to sign an agreement and to provide information about his children's daily/weekly activity with computer. According to our pre-experiment questionnaire all participants used computers more than once per week, but not more than 20 min per day; their daily/weekly computing activities were YouTube movies, mostly series “Masha i Medved”.

As all children in the experiment were familiar with YouTube and series of “Masha i Medved” movie, all situations were created to imitate UI for YouTube movie view. Children were asked to sit by the computer and to choose which movie they want to see. Children were allowed to click on the picture by themselves, however as some children did not know how to play the movie, they were helped by the personnel - a child had to look at the movie scene and to tell which of these movies he or she wanted to see.

There were 5 different UI, which had multiple starting scenes of the movie on each of them, located in different places of the screen. The number of 5 experiments was chosen to make sure the child will not get bored. As well the size, dimension of the movie scene were constant for all pictures. Changes were made only in location of the pictures (random position with no overlapping pictures) as well as two tasks out of five had one new scene as all other were always the same. The additional, unseen scene was added to increase the motivation of the child, as all scenes for him or her are already seen and the new one will be interesting and exciting. All five situations were presented for child in the same order:

1. 6 pictures (all the same) of a starting scene of a well-known animation movie.
2. 6 pictures (all the same) of a starting scene of a well-known animation movie in different screen locations.
3. 5 pictures (all the same) of a starting scene of a well-known animation movie in different screen locations.
4. 4 pictures (all the same) and 1 new of starting scene of a well-known animation movie in different screen locations.
5. 4 pictures (all the same) and 1 new of starting scene of a well-known animation movie in different screen locations.

The choice to use multiple pictures was done to model situations when a user has a choice which object they want to pick, which way is more suitable for them to do a task they want etc. rather than executing automatic actions to look at one specific object. As the size of the pictures was constant we changed the number of pictures to force a change of distances from one picture to another. As well the number of 6 or 5 pictures was chosen to fill the screen with pictures, distancing each other approximately the same length as the pictures' width. This allowed us to make sure there will be enough space between each object.

All experiments were executed separately for each child to make sure there will be no distractions. As well the experiment room was locked to prevent distractions from outside. To make sure the child will be calm he or she had time to get to know the room and the equipment. Then step by step the EEG and eye gaze tracking systems were set to track child's brain activity and eye gaze movement. EEG was analysed using EPOC Emotive system where all types of brainwave were recorded for later analysis. Mirametrix eye tracking system was used to track eye gaze movements in order to find out what the child saw, where his eyes were looking at. The system logged monitored coordinates were the child was looking. By synchronizing in time and combining data of brainwave activity and eye gaze movement tracking we were able to identify the correlation between these two sources.

As well all experiments were filmed (both laboratory and working monitors, with all acting systems and executed actions) and summarized by independent observer. The task for independent observer was to log information what the child did, how he acted, etc. The data was useful to analyse possible causes of changes as well as correlation to the child's actions and brainwave activity as well as eye movement.

To ensure the research is compatible with ethics and law in Lithuanian in April, 2014 Lithuanian Bioethics Committee gave their consent to the study, which was done using special EEG, Eyes Motion tracker and Video hardware and software for 2–4 year old children. The Committee decided that the measures are compatible with research for children's rights and is not forbidden.

III. RESULTS OF THE EXPERIMENT

Synchronization of EEG signal data, eye movement tracking logs, experiment video records and paper notes of independent observer is required to get a full view of the research. It was done by using the same global time in all of these parts, therefore synchronization at millisecond level was achieved (except the observers data, it has approximately at 3 seconds accuracy).

In the first phase of result analysis the child's motivation level was observed by analysing Beta and Gamma brainwave activity. For each child's experiment a chart of brainwave activity changes in time was made and all times were marked when the eye movement to the object started. Moreover observer's notes were marked to identify additional child's activities during the experiment.

The data cannot be averaged for all 14 children, as there is a big variety in time when child decided to see the movie, what he or she does between different situations etc. Therefore example data of one child brainwave activity in our experiments is presented in Figure 2 and presents main tendencies, noticed in data of all children.

In Fig. 2 vertical lines with numbers from 1 to 5 identify the task execution start time. Usually after the task was given and before the task was done the child's beta and gamma brainwave activity increases and starts to decrease after the task was done. It shows that a child concentrates on the task. Children think on what they should do, while after the task is done allow a loss of concentration. This increase of both beta and gamma brainwave activity matches the theory of focused attention in the literature [35].

As the research used 2 year–4 year old children, additional activities were noticed during the brainwave monitoring. As the example in Fig. 2 shows, the child after task 1 up to task 2 had more jumps in brainwave activity (area A). In this case it was a child's discussion why after choosing the movie it was not working. Area B shows a situation when a child was distracted by other activities, usually a conversation with parents *etc*. In this case the beta brainwave activity decreases as a child knows he or she does not need to do any tasks, while concentration might increase.

Task 4 included a new scene. In this case all children showed an increase of gamma brainwave activity. Usually this activity does not decrease instantly (area C) as the child really wants to see a new series of the movie and starts interaction with surroundings on why it's not shown. After some time of the task 4 the gamma brainwave activity decreases as children usually lose hope to see the movie. So the task 5 increases both beta and gamma brainwave activity, however the focus is not as high as in task 4, despite the same new scene of the movie that was shown in the task again.

According to the results of brainwave activity analysis we classified all tasks for each child into no aimed (where gamma frequency increased less than 2 Hz) and aimed (where gamma frequency increased more than 2 Hz). The Non-aimed object represent starting movie scenes which were selected by children, however with not such an immense interest (just because they had to choose one of them). Meanwhile aimed objects were those scenes, which were selected by children with a big interest, revoked by themselves. Therefore usually only task 1 and task 4 was classified as aimed.

After all tasks were classified into aimed, no aimed and not executed (children refused to continue or did not execute the test as requested), the analysis of eye gaze movement was executed to find out how the motivation changes the eye gaze slope in Fitts' law. This was done analysing the eye gaze movement logs. As the log stored data of all eye movements in the screen, we were able to identify not only the beginning of eye movement but the concentration on certain object (end of the eye movement to a specific target) too. First of all eye jumps were classified into two categories: those who stopped on the area of object, picture; those who did not reach, overlapped with any object. Then according to eye gaze movement data for each jump which reached the movie scene picture the jump duration as well as distance to the object's centre and its width was determined.

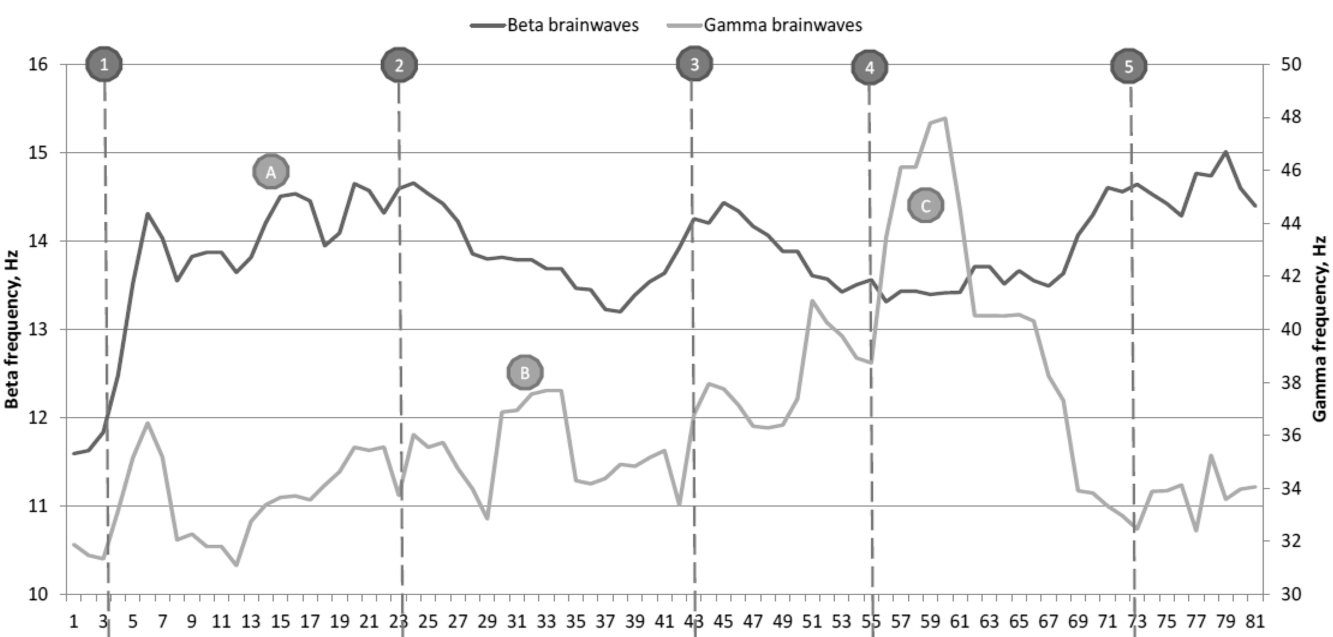

Fig. 2. Example of one child's beta and gamma brainwave activity during experiment with 5 different situations.

The data were enough to calculate the index of difficulty (2) and to get the slope value (b from (1)) as we assume there is no reaction time a. This assumption was made as specific time or event was not given for the child to start the task – children decided by themselves when they want to look at a certain movie scene.

One of the most obvious results we obtained according to these data – if the task is aimed children always reach the object within target's area. Therefore if a new scene of a well-known movie was noticed, the motivation level rises and eyes always go to the new object (regardless of whether it is at a greater distance comparing to other pictures). Meanwhile if the task is non-aimed, same child looks over a couple of targets, one after another and even 17 % of eye movement is close to the target, however they do not reach it. This shows the child might just overlook, not concentrating on one target.

To analyse eye gaze slope, according to Fitts' law we took all data of eye movement from any source area (blank area or another picture) to the target area (picture of movie scene). In total there were 8 aimed and 35 non-aimed targets (see Fig. 3).

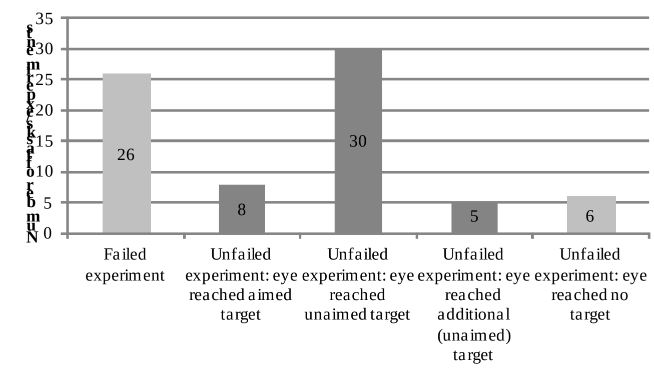

Fig. 3. Summary of successful and unsuccessful tasks with children in the experiment.

By applying all eye movement data of reached targets to Fitts' law calculated slope for each of them and found out that the average slope for non-aimed tasks is 1.07 (std. 0.68) and for aimed tasks – 0.21 (std. 0.12). The difference of slope value for aimed and non-aimed tasks can be seen in Fig. 4. It showed that the eye movement in aimed tasks is approximately 5 times faster, comparing to non-aimed tasks.

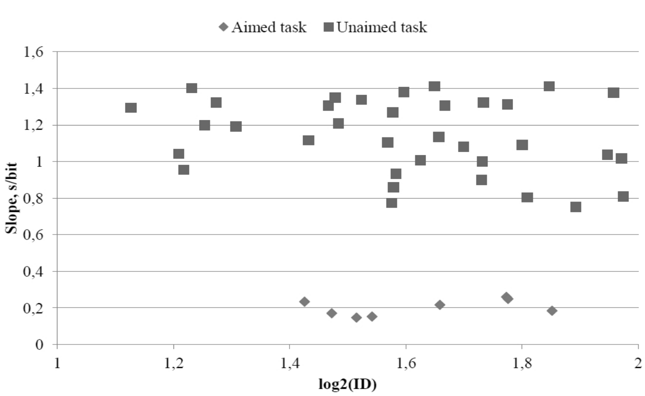

Fig. 4. Slope dependency on tasks index of difficulty and motivation level.

In our experiment all movie scenes were of the same dimension, therefore the index of difficulty mostly depends on the amplitude A (the width of the target might vary as well as the objects were rectangular, however the standard deviation of the width W is 14 % of radius a circle would have with the same area all rectangles had). Analysing the correlation between index of difficulty and task type (aimed or non-aimed) we do not want to raise any significant results as the position of movie scenes were randomized, however the minimum value of index of difficulty is greater in aimed tasks, comparing to non-aimed (see Fig. 4). It indicates the same tendency we noticed while analysing the filmed material of all experiments – if a child sees a new scene he is motivated to reach the exact object, despite the fact there is another one within a smaller distance.

Even though there are a deviations on eye movement speed, the line between aimed and no aimed tasks is clearly distinguished according to the slope value b. This allows raising a hypothesis that the motivation level can be calculated according to the eye movement slope. However it can depend on the situation and for some tasks, which are not as different as in our case, the line can be unclear for clustering only on eye movement, rather than both brain activity, eye movement and human supervision.

IV. Conclusions

As some researchers state [31] and our experiment shows with different tasks, the motivation level can be identified according to the beta and gamma brainwave activity. Experiments with children from 2 to 4 years show their brain activity is not constant and changes many times (in this experiment variation for beta brainwave were 11–16, for gamma – 30–50), probably the influence of many different factors, not only the task itself. The fact eye movement slope is significantly different in aimed and unaimed tasks, shows we decided correctly to indicate motivated tasks if the gamma brainwave increase is more than 2 Hz.

The motivation level is a big factor for eye movement of 2 to 4 years old, as aimed objects are reached even up to 5 times faster by the eye comparing to unaimed tasks, where lack of motivation exists and overview method is sometimes used rather than straight look into one object.

For children of age 2 to 4 years new objects increase the motivation, however just temporary as the same object, shown second time, can be threaded as known an uninteresting for the child. Therefore the graphical user interface should always change in some manner to attract small children more.

Experiments with age of 2 to 4 years are complicated as only 54 % of tasks were executed properly. Therefore to get more accurate data in experiments with children of this age, the number of children should be increased or executed multiple times to get more data to analyse.

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Analysis of the Pattern for Icon Selection and Relation to Positive/Negative Actions in Desktop Applications

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Abstract

The paper presents an experiment on selecting and identifying an icon in desktop applications. The aim of this work is to get more specific guidelines for improvement in the design of a natural user interface. By conducting an indirect survey and handling different tasks to users, the issues such as what usual patterns for overviewing an icon in desktop applications are, how these patterns change when a user has to make a decision on what icons must be selected, how the pattern for selecting the icon varies and what changes in selection time take place when a task is executed multiple times in a row have been considered. To examine the influence of decision making on icon selection, icon classification into the positive and negative ones has been employed. As users had no guidelines what a positive/negative icon was, the ability to analyze if the colour of the icon and a related type of action influenced the perception of the icon has been developed. The carried out research draws the basic patterns for overviewing the icon in desktop applications and proves that the colour of the icon or the related type of action cannot be used as a single property to indicate icon perception by users.

Keywords: Icon; user interface; desktop applications; human-computer interaction.

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1 Introduction

The user interface (UI) is one of the most important elements in the successful promotion of software among those applying it in practise. The user interface has to implement software functionality, to be easily applied and intuitive for different types of users. The design of a suitable UI is a challenging task and requires knowledge of Human Computer Interaction (HCI) in order to create a successful Natural User Interface (NUI), as every situation can be unique. Therefore, what is suitable for one project can be a failure for another; it requires a wide variety of knowledge to design a successful UI. The user interface designer must be sure that all important properties and psychology of the customer have been taken into account and that technical abilities to implement different elements of the user interface have been properly considered. The complexity of the task for UI design can be highlighted by the fact there is no clear, unambiguous rules of how to design a good user interface. There exist only different guidelines and proposals for how to create a suitable UI or a particular type of software for a certain group of users [1]-[8].

A rapid change in technologies and new HCI methods change the user's perception of UI usability. Therefore, knowledge of the NUI has to be frequently renewed; otherwise, it will lead to a failure rather than successful user interface design. Therefore, even the most useful and functional systems have to be updated in order to meet new UI tendencies and user requirements. The aim of this paper is to get more specific guidelines for improvement in natural user interface design, which will be done analyzing the properties of user's work on icon-based desktop applications thus presenting the situation observed in 2013 – 2014. As new ideas of UI design takes time for spreading worldwide, these guidelines should be helpful in 2015 and in the future if no drastic changes emerge in this area.

2 State of the Art

One of the elements used in the UI is an icon – a sign or representation that stands for something by virtue of a resemblance or analogy to it [9]. It plays an important role in the NUI as one good icon can tell more on its purpose comparing to multiple words or even sentences used for describing the function. Therefore, some researches have been done in this area to get more data on the usage, importance and clustering of the icon. Mack et al. [10] suggested that a particularly meaningful icon in displays could capture our attention, and therefore a meaning had to be added to the icon. McDougall and Curry [11] examined a broader context of interpretation from a cognitive psychological perspective by analyzing the effects of workload and task complexity, user preferences and aesthetics, time for day effects and user skills. The results of these works proposed additional guidelines. However, the relationship between the icon and the function is not determined by a set of well-defined syntactic and phonological rules. Icon interpretation is still ambiguous and no laws are presented to determine the quality or success of the icon among its users. It is important to find as many factors influencing the success of icon usage as possible in order to better understand this area.

The role of relationships can be noted in works by Niemela and Saarinen [12] as well as in those by Richards and McDougall [13]. These authors analysed the importance of icon clustering. According to the obtained results, icon clustering allows more effective icon search as well as quicker identification of icon-function relationships. These findings are useful for designing the UI with the help of multiple icons; however, no data on designing one specific icon are given. Research on specific icon design was done by Hg and Chan [14] who analyzed three visual features (colour, surround shape and icon size) and five cognitive (familiarity, concreteness, complexity, meaningfulness and semantic distance) features of the icon. The results of the conducted research on colour importance do not meet with those obtained by Courtney [15] who proved colour was commonly used for communicating with the meaning – red for danger, green for 'go', etc. Colour conventions appear to have reasonable cross-cultural transferability in Courtney research. Meanwhile, Hg and Chan confirmed the colour of the icon was not the only factor as other properties had to be taken into account to determine icon suitability. They also, among other properties, did not give a quantitative evaluation of icon effectiveness or a factor in colour importance. However, more works state the colour has a big influence on icon usage: Wang et al. [16] found the pictorial-colour was a significant factor in the visual identification of subject performance; Shieh and Huang [17] revealed the pictorial size and circle-slash thickness influenced glance legibility for prohibitive symbols under degraded situations; Duarte et al. [18] indicated the pictorial symbol, colour and shape influenced understanding the symbol.

Understanding the problem of icon usage is very complex. Thus, some researchers analyzed very specific situations: designing a web icon for travel websites [19]; mobile interface icons [20]; context-aware navigation in mobile games [21]; differences in shallow and solid icons [22]; analysis of the icon for specific purposes [23]; etc. Most of researches investigating the properties of icon usage in a specific area received clearer data, tendencies and insights compared to researches where, at the same time, a very wide application area was analyzed. This shows that icon interpretation and usage depends on the type of application (web, mobile, desktop application, etc.). Unfortunately, the existing researches on different types of the UI concentrate on the identification of icon context rather than on the patterns identifying the relation or selection of the icon. Meanwhile, these two properties are important for the NUI as the relation of the icon holds the first expression and unconsciously influences the judgment of the icon and the system; also, the pattern of icon selection can give guidelines on how icons should be ordered to fit natural user behaviour and to increase system usability.

Time for task execution is one of the most important metrics in HCI and NUI. It allows estimating how quickly the user is able to execute a task and how much time s/he has to waste and wait because of input device properties or an improperly designed UI. Fitt's law [24] proposes a formula for calculating time needed to go from one point to the centre of an area of a certain size. This law is still relevant and used; however, additional data are needed to be able to adopt this law for a successful design of the NUI: if we know users and typical UI overview patterns, we can calculate the most probable time for eye movement needed to overview the UI; if we know what icons are the most noticeable, we can predict time for eye movement needed to find a certain icon. Therefore, this paper analyzes icon selection properties in the icon-based desktop environment and seeks for two main goals:

- To get data on icon overview patterns that assist in selecting an icon in the desktop environment.
- To highlight some properties that could indicate whether an icon will be related to positive/negative actions treated as positive/negative.

3 Methodology

As mentioned above, the pattern for selecting the icon is an important factor in the NUI. If we knew the pattern for overviewing and selecting the icon, we would be able to group and place icons according to their importance and the frequency of usage. A typical pattern for overviewing the UI can be identified experimentally. Software usability is usually evaluated by means of different methods, including reviewing standards, user testing, subjective assessments and barrier walkthrough [25],[26].To make sure we will get more realistic results the prospect of indirect survey was chosen. For conducting the experiment, an internet tool has been created to imitate the icon-based desktop environment.

Typically, users have two main eye movement tasks in the UI: the user overviews the whole UI in order to inspect functionality, and the user searches for specific information and the function he needs. Overviewing the UI requires going through all icons while search in the UI requires going through all or some icons in the UI and selecting only the specific ones. Our experiment had to imitate both situations. For the overview, we required to select all icons on the desktop to make sure the user saw the icon. As for the task searching for an icon, we asked the user to select positive/negative icons. This additionally allows estimating properties influencing user opinion on icon positivity/negativity as well as ensures they do not need to remember the icon list we asked to select. If a certain list of icons were given to select, we would have one more unknown parameter in this research – how well the user is capable of remembering what s/he needs to find. Meanwhile, in real life, the user usually decides on what to select by him/her. Tasks to select positive/negative icons should be unusual for all users, and all of them should have no prejudgements what have to be selected. Therefore, we could get data on how selection time changed when a task was given for the first time and repeating it multiple times. This type of the task presents a situation when users make a decision rather than try to remember what have to be selected.

Every experiment involved twenty icons placed in different places of the virtual desktop (Table 1). The icons were chosen to present all main icons, which most of users met working with desktop applications. The biggest part of icons cannot be met directly on the desktop; however, they can be seen in different software or the Windows operating system (Windows operating system is applied, as the major part of Lithuanian people use it because it is known and popular). This allowed us to prevent from prejudice where a specific icon should be in a real desktop environment and to make sure all icons are known to the user that has some experience of working with them.

Also, we assigned the main colour and type of action for each of those icons (Table 1). It was done before the main experiment using a separate group of 26 persons. Each of them had to identify what the main colour (only one colour) of the icon was. All persons were asked to select whether the icon was associated with creation, destruction or neither of these actions. This allowed us to get preliminary classification of icons. At this stage, we did not want refer to the same users as in the real experiment by seeking a more general estimation of all icons in the main experiment as well as by keeping the properties and purpose of the experiments in secret for all users before the main experiment.

Table 1. List of icons used in the experiment

No.	Icon	Title	Main colour	Action type
1.		Copy	Blue	Create
2.		Paste	Other	Create
3.		Edit	Other	Create
4.		Help	Blue	Other
5.		Search	Black	Other
6.		Save	Blue	Create
7.		Confirm	Green	Create
8.		Delete	Black	Destroy
9.		Recycle	Black	Destroy
10.		Error	Red	Destroy
11.		Cut	Blue	Destroy
12.		Close	Red	Destroy
13.		Warning	Other	Destroy
14.		Shutdown	Red	Destroy
15.		Picture	Blue	Create
16.		PDF document	Red	Create
17.		Email	Other	Create
18.		Search	Blue	Other
19.		Exception	Green	Destroy
20.		Sound	Black	Other

The main experiment involved all users having to execute three different tasks:

1. To choose all icons from the desktop (by clicking on it) in any order they want.
2. To choose all positive icons from the desktop in any order.
3. To choose all negative icons from the desktop in any order.

The early stages of this experiment showed usual, non-disappearing icons that influenced much dissatisfaction from users in Tasks 2 and 3. The users complained they did not remember what they had already selected. Sometimes, even user frustration was noticed, and therefore different solutions were considered for this survey. Solution to disable icon after selection was eliminated as current desktop applications do not use this practice very often and it would be unusual for users. Meanwhile, icon elimination from the working window is common to many systems of design. Therefore, we decided, after clicking on the icon, it would disappear from the desktop. It gives multiple bonuses to this experiment as the user has no chance to click twice on the same icon doing the same task; it is similar to rating a natural object when the user eliminates the chosen element from the list; it helps with tracking what icons have already been selected and to decrease the number of icons to click.

No explanation in which order icons have to be selected or what should be treated as a positive/negative icon has been given to users. It was done in purpose to invoke the user to find his/her way with no predefined requirements or measurements. In addition, the experiment was executed three times randomly changing the place of icons. The repetition of experiments allows us to eliminate anomalies in user actions as well as to examine if these actions change executing the same task multiple times in a row.

137 users took place in this experiment during the period from May 2013 to September 2014. They also had to provide some data on their gender, age group (from 7 to 14; from 15 to 19; from 20 to 29; from 30 to 39; from 40 to 49; from 50 and above), a field of occupation (Economy, Physiology, Psychology, Technical and Technology scope, Law, Management, Other) they belong to and the country of origin. All personal data were used for analysing if it influenced the pattern for selecting an icon or related results and did not require any specific personal data that could be related to a certain person. The survey was open and everyone who knew the address of the study had a chance to participate. Participation was voluntary. The first page of this tool introduced research as the scientific one. A note shown to all users indicated they had to be at least 18 years old or have a permission of their parents or tutors to attend this experiment.

The results of 69 men and 68 women were analyzed. All other categories were distributed not so evenly; however, at least 3 persons were participating in each category considering age and the field of occupation. Also, there were 19 respondents who did not live in Lithuania at the moment of the survey (9 different countries).

During the experiment, we logged on the selected ID of the icon, a location on the desktop, icon classification into positive or negative, icon selection order, icon selection time, task number, repetition number and mouse click/icon position on the desktop. To simplify the randomization of icon position (as no icons can be placed in the same place or too close to each other) and storage in the log, the desktop was divided into 8 columns and 8 rows, which allowed having 64 different cells on the desktop (Fig. 1.).

4 Results and Discussion

All experimental data were carefully analysed from different perspectives. Two main goals have been established in this paper, and the obtained data have been grouped into two subsections each of which will be presented.

Fig. 1. Example of the experimental environment where all icons are placed randomly on the desktop area and black lines indicate to which cell (column and row) the icon belongs to

4.1 Analysis of Icon Selection Properties

One of the most important measures for the UI is the distance the user has to cover from one click to another. The analysis of the experiment shows that the distance of mouse movement between two clicks depends on the age of the user (Fig. 2). The youngest participants (up to 15 years) showed the capability to choose all icons in the shortest path while all other age categories reported similar results – the average distance between two mouse clicks were from 2.21 to 2.24 of cell width. No tendencies how other user properties (gender, occupation, etc) influences the icon selection distance were noticed during the analysis.

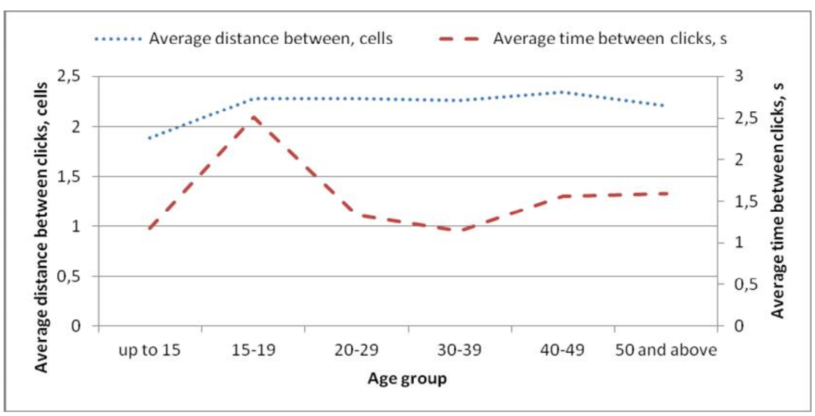

Fig. 2. The average distance of mouse movement and time between two clicks considering the users of different age groups participating in the experiment

Next, distance in cells rather than in pixels is calculated, as the size and resolution of the screen for each user might differ. Also, the distance between cell centres is estimated, as the icon is usually placed in the centre of the cell, and we have logged only the cell rather than an actual mouse position in the screen.

Time is another important measure for the UI. The number of the selected icons might differ considering each user in a different task; therefore, the average time between two mouse clicks was compared and made 1.65 seconds. However, we noticed that the maximum time between two clicks was more than 2 minutes, and 8 times for selecting an icon were found unexpectedly large. This shows these users made some breaks or were disturbed from the task. Therefore, we eliminated all records within the intervals of more than 30 second between mouse clicks and used only the corrected data on time calculation. This allowed obtaining the average time between mouse clicks equal to 1.351 seconds.

The analysis of the average time between two mouse clicks showed interesting results as the age group from 15 to 19 years was slower comparing to other age groups (Fig. 2). The age group from 15 to 19 has the greatest standard variation in time (2.11), which shows the users of this group are very different and unstable as a deeper analysis of data on separate users have showed there are respondents with longer time between mouse clicks as well some users having a wide range of times. In opposite to this group, the age group of up to 15 years showed a very constant speed for all clicks (were executed up to 2 seconds). This also can be related to the distance between mouse clicks – this group had a smallest distance between clicks, and therefore, according to Fitts' law, [27] time should be shorter as well.

To evaluate all events of all age groups or even of the users meeting Fitts' law, this experiment would be not correct. Fitts' law takes into account reaction time and task difficulty, which depends on target distance and width. As regards this experiment, all targets are of the same width, and distance to the target should be the same as that between two mouse clicks; nevertheless, no data on what is the reaction time of the users are available. Meanwhile, reaction time can vary extensively in this experiment, particularly if the user needs time for deciding what a positive/negative icon is. The importance of reaction and decision time can be noticed examining variation in time between two mouse clicks – time to go from one cell to another can be different for the same user in different tasks. The analysis of the average time between mouse clicks during different tasks and repetitions differ (Fig. 3). The first task requires less time for going from one icon to another comparing to Tasks 2 and 3, as the user does not need to think what s/he identifies as a positive/negative icon. It meets with Hiko principle stating that the time it takes to make a decision increases proportionally to the number and complexity of choices [28].

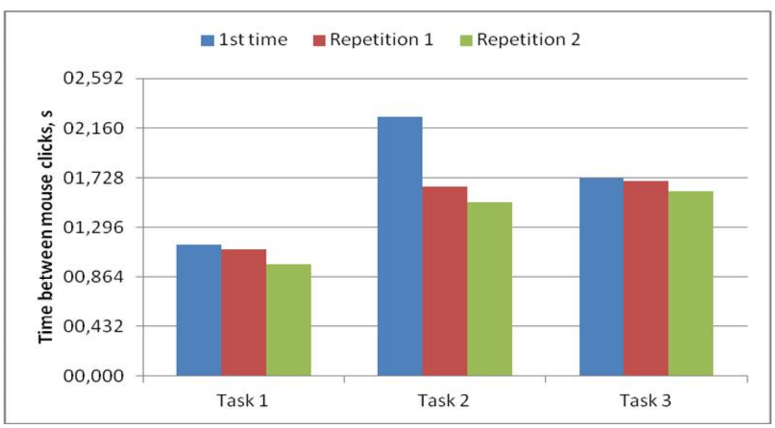

Fig. 3. The average time of mouse movement between two clicks considering different tasks and repetitions

Principles of Gestalt psychology state that the icon is recognized easier if it was selected once before [29],[30]. We also have obtained analogue results, as time between two mouse clicks is decreasing each time the user repeats the task. It shows less time is needed to identify the icon as positive/negative. However, the times of Tasks 2 and 3 do not reach those of Task 1, and this means there is additional thinking in Tasks 2 and 3 (need to decide once again or to remember what to choose) comparing to Task 1.

Also, the difference between tasks can be noticed analyzing the average distance between mouse clicks (Fig. 4). Tasks 2 and 3 have a longer distance between two mouse clicks comparing to Task 1. This can be explained by the fact that the distance between the icons increases as not all icons must be selected. Besides, it is possible the user selects these icons starting from the most positive/negative to the least positive/negative one, and therefore does not try to use the shortest path in contrast to Task 1.

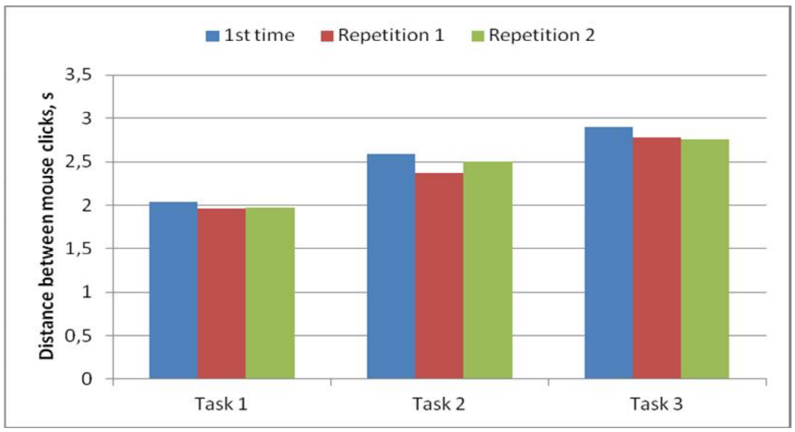

Fig. 4. The average distance of mouse movement between two clicks considering different tasks and repetitions

Fig. 4 shows the distance between two mouse clicks does not vary greatly when the task is repeated. A decrease in the distance between two mouse clicks can be achieved by optimizing the icon selection path; however, it can be difficult to achieve if there are too many icons to remember and to find the shortest path between them. Apparently 20 icons are too many to remember, or the shortest path was optimal at the first attempt in Task 1. Meanwhile, regarding Tasks 2 and 3, a decrease is larger comparing to Task 1. It might indicate some optimizations were done, however it is not as big as it could be.

The analysis of how (in which direction) the user usually chooses icons reveals that the biggest part of users has the same start strategy. Task 1 shows how users start from the left-top corner and go to the right or down. Later, they follow the opposite direction or start from a new column/row. Therefore, the first icons the user chooses in Task 1 are usually in the left-top corner. Fig. 5 suggests that the average icon selection order is the smallest in the top-left corner and increases crosswise at the right-bottom corner. However, a more detailed analysis of icon selection order showed a tendency to go from the left to the right one line by one, which is more frequent than going from the top to the bottom column after column.

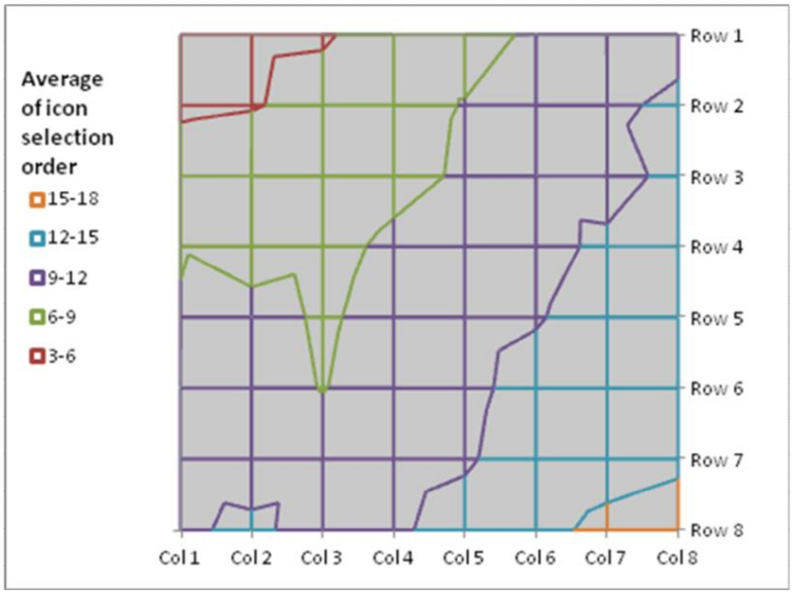

Fig. 5. The average order of the selected icons accordingly to the cell of the desktop

An interesting point is that the same pattern for selecting the icon order applies to Tasks 2 and 3. This shows the same "desktop scanning" method is used not depending on what the user has to choose, as s/he overviews the desktop in the same order. We should add the order might be influenced by a position where the user starts the task as buttons for starting and finishing different tasks are also located on the top of the desktop.

Despites the user starts selecting icons from the left top corner, the smallest distances are in the middle of the desktop (Fig. 6), which indicates a natural situation as the distance from any place on the desktop is shorter to the centre rather than to any other place on the desktop, particularly corners. However, it does not match with data we can see in Fig. 5. Before obtaining results, the user clicks all icons in a grid fashion style (each row or column one by one, rather than randomly). An explanation can be found in Fig. 7 showing how many times the user clicked on each of the cells on the desktop in Task 1 (it applies to all 3 tasks). As users had to choose all icons, this diagram also illustrates how icons were distributed during the experiment. As more icons were placed in the centre, it is natural the distance between two mouse clicks in the centre is smaller than that in the corners where less icons are placed.

The analysis of user age, occupation and other demographical data showed no significant influence on execution metrics of these three tasks.

4.2 Analysis of Icon Classification into Negative/Positive

Data on Tasks 2 and 3, to get information on what the user treats as a positive/negative icon, have been analyzed. These two tasks required to select only the icons the user thought to be positive/ negative. The average number of the icons users chose as positive was 11 out of 20, while that of negative ones – 9 out of 20.

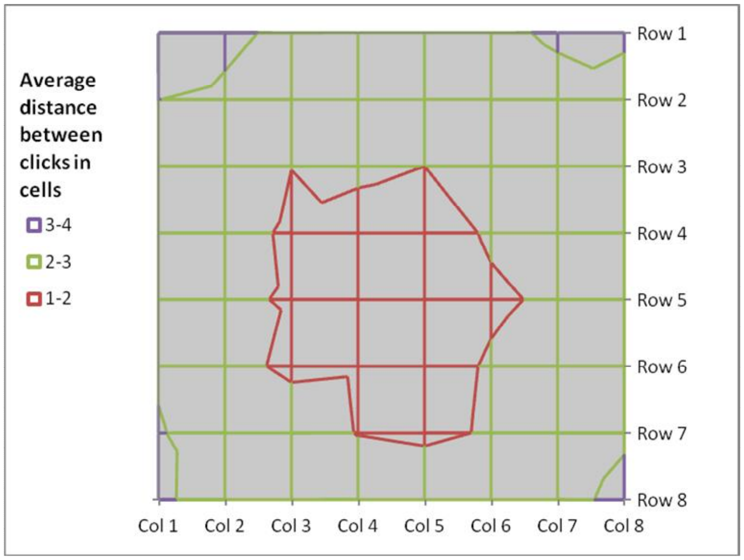

Fig. 6. The average order of the selected icons accordingly to the cell of the desktop

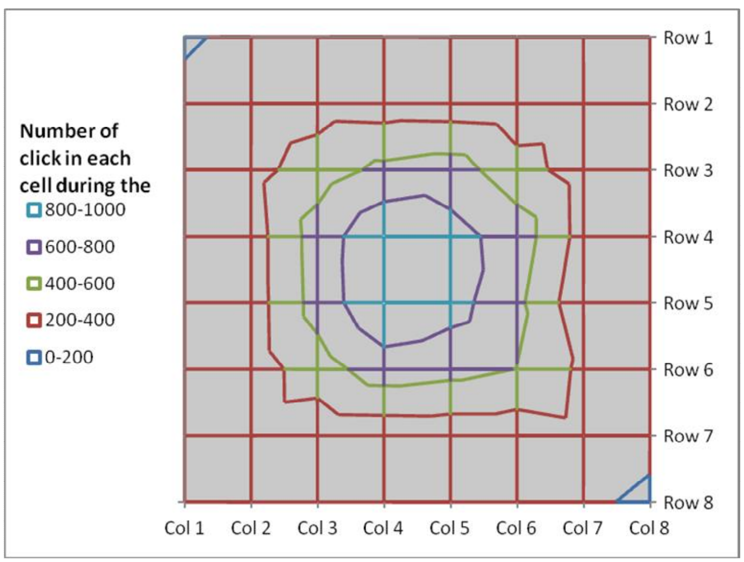

Fig. 7. The average order of the selected icons accordingly to the cell of the desktop

In the beginning of the experiment, we had a hypothesis that the colour of the icon would be one of the most important factors indicating if the user treated it as positive/negative. After data analysis, despites the colour, we had a very similar identification of the icon as positive/negative (Fig. 8). We can notice red icons are found as positive more rarely comparing to other colours, particularly black; however, difference is only 1%. Meanwhile, users more frequently discover red icons as negative comparing to other colours; nevertheless, the difference is also only up to 1%, which is not enough to make some conclusions depending on the colour only.

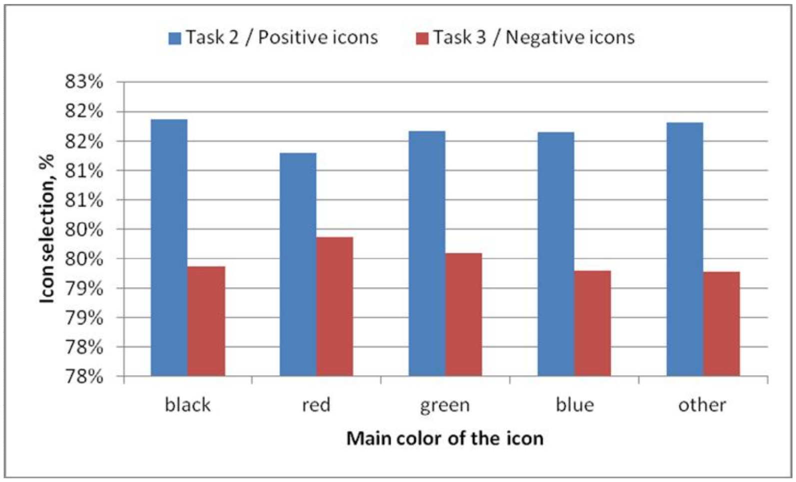

Fig. 8. The distribution of selecting an icon according to different colours

Task 2 shows that users, first of all, choose green icons, while the red ones are the last ones they prefer (Fig. 9). In the meantime, Task 3 indicates the icons of the red colour were selected in the beginning, while the blue ones in the end. This means the colour has an influence on icon classification into positive/negative; however, the colour is not the only property of determining whether the icon is positive or negative.

Analysis if the related type of the action of the icon has an influence on icon identification as positive/negative has been conducted. Similar results as those of the colour have been received – on average the icon of each type of action was selected by 91% of users in Tasks 2 and 3. Still, the order of icon selection gives more data (Fig. 10): as for Task 2, first of all, the icons that mean creation were selected while those related to destruction were selected the last; Task 3 shows that, first of all, the icons that mean destruction were selected while those related to the creative action were selected the last.

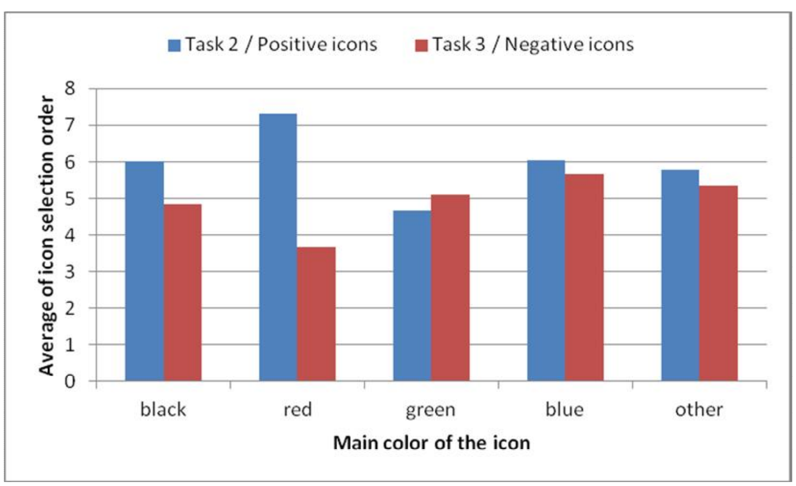

Fig. 9. The distribution of selecting an icon order according to different colours

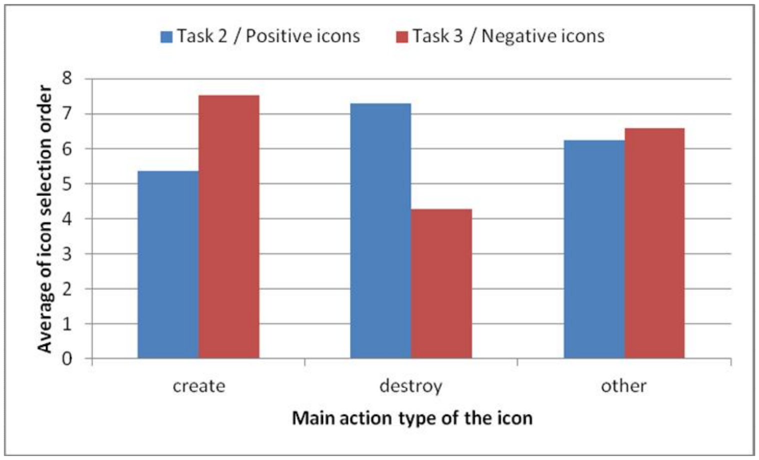

Fig. 10. The distribution of selecting the icon order according to different types of actions

The combination of both properties (icon colour and a related type of action) has an influence on identifying the icon as positive/negative. For example, a green icon that means a creative action was always selected as positive within the first 8 icons as well as the red one that refers to destruction – as negative. However, it seems there are more factors influencing icon classification into positive/negative (personal experience, etc.).

The analysis of how separate icons were classified to positive and negative by the participants of the experiment has also been carried out (Table 2). The obtained results suggest all icons were selected as positive/negative approximately by 79-82% percent of users. This shows there is no strict division into a positive or negative icon.

Table 2. List of the icons used in the experiment

No.	Icon	Percentage of the users who selected the icon		Average of selection order for the icon	
		Task 2 / “Positive”	Task 3 / “Negative”	Task 2 / “Positive”	Task 3 / “Negative”
1.		82%	79%	5.87	8.35
2.		82%	79%	6.02	10.77
3.		82%	79%	5.89	7.86
4.		81%	80%	7.40	5.81
5.		82%	79%	5.81	7.89
6.		82%	79%	5.42	7.73
7.		82%	79%	4.09	7.67
8.		81%	80%	6.89	4.24
9.		81%	80%	7.94	5.15
10.		81%	80%	9.92	3.70
11.		81%	80%	7.38	4.95
12.		81%	80%	6.47	3.58
13.		81%	80%	7.48	4.56
14.		81%	80%	6.64	3.73
15.		82%	79%	5.53	5.48
16.		82%	79%	5.93	7.22
17.		82%	79%	4.74	6.37
18.		81%	79%	6.34	8.58
19.		81%	80%	6.98	4.72
20.		82%	79%	6.12	6.30

As icon colour and related action cannot be used as single criteria for icon classification into positive/negative, we tried to analyze if neighbouring icons influenced icon classification into positive/negative. Therefore, each user of a positive/negative icon selected in Tasks 2 and 3 was related to (depending on a situation up to 8 icons placed in the connecting cell of the desktop) colour and action types of neighbouring icons. As icons were placed randomly on the desktop, there were not enough cases of 9 identical cell combinations to get significant results of the carried out analysis. Meanwhile, the examination of the icon pair (selected icon and its neighbouring icon) had more data. However, the correlation between selecting the positivity/negativity of the icon and a neighbouring colour, action type and positivity/negativity in the same task were too small to exhibit tendencies. This shows the random function was not able to place the icons of similar positivity/negativity level. Besides, it shows that the user analyzes all icons separately to classify them as positive/negative rather than rely on its surrounding.

If we added an additional requirement for selecting a limited number of positive and negative icons, the situation could be slightly different as when analyzing selection order, more obvious results could be noticed. According to the average selection order, the positive icon would be Confirmed, Email, etc., while the negative icon would be Close, Error, Shutdown, Delete, etc.

4.3 Specification of Some Bruce Tognazzini Principles

Bruce Tognazzini made a list of the main principles regarding UI design [31]. It is one of the most combined materials we have to deal with to ensure the UI will be suitable for usage and satisfaction. These principles are not meant for one specific type of application only and used as "must have" in many cases. Most of Tognazzini principles are abstract and have no exact property value or another measurement how to evaluate if something is achieved or not. The same idea exists in almost all best practices in order to present a guideline or an idea rather than measurement, taking into account it might vary in different situations. The obtained results allow specifying some of Tognazzini principles (Table 3).

Table 3. Specification of Tognazzini principles

Tognazzini principle of interaction design	Suggested specification for icon-based desktop applications
"If the user cannot find it, it does not exist"	The most important icons should be placed in the top-left corner as the user usually starts overviewing the desktop from this place.
"Look at the user's productivity, not the computer's"	Related icons should be placed close to each other as the user first overviews the icons close to the current position rather than "jumps" through more than the radius of 2-3 icons out of the current position.
	The same icon or its usage sequence should be similar in order to increase task execution time, as multiple usages of the same task eliminates decision time and speeds up task execution time.
"Do not strip away or overwhelm colour cues in the interface because of a passing graphic-design fad."	The colour is not the main component that forms impression on the icon. The previous experience and associations of the user might be more important rather than the colour only.
"Choose metaphors that will enable users to instantly grasp the finest details of the conceptual model"	Item colour or associated action as single property are not enough to predict icon success among users; there are more unknown factors, and therefore the already known icons should be used or new ones should be examined by the users before real usage.

We also would like to notice that these specifications are for icon-based desktop applications only and apply for the period 2013 – 2015. Hence, these experiments should be repeated time to time to make sure user behaviour has not changed.

5 Conclusion

The executed experiment using an indirect survey has showed the same tendencies towards selecting icons in the desktop environment as Hiko and the Principles Gestalt psychology suggest. However, we did not get any significant data on what influences icon relation to positive/negative, and the principles of the colour theory could not be approved.

Changes in icon selection depends on is icon selected during automatic task or task which requires additional decisions to be made. This is proved numerically as average time for moving a mouse from one icon to another is up to 2 times faster if the user does not need to make any decisions on choosing the icon. Also, our experiment showed none of the users was able to select the icon faster in Task 2 or 3 comparing to Task 1. This demonstrates an additional time is needed to make a decision.

A comparison of selecting the average distances of the icon in Task 1 showed the youngest age group was capable to select all icons within the shortest path where the average distance did not reach 2 cells. This might be an indication the elder persons gain additional experience and can be distracted by some icons that do not allow them to follow a certain strategy for icon selection.

The conducted experiment showed the positive/negative icon cannot be estimated only by its main colour and action type. These two characteristics influence the selection orders of positive/negative icons. However, these two characteristics are not enough to estimate what the user will select as positive/negative. All users have different experience, which additionally may influence how many icons he will treat as positive/negative and what kind of icons they will be. In order to estimate all influencing factors in icon classification into positive/negative, more additional data have to be gathered from individual users (open questions why he chooses an icon as positive or negative, the previous experience of working on the icon, etc.).

Competing Interests

Authors have declared that no competing interests exist.

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