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| tallinna tehnikaülikool | |
| Infotehnoloogia teaduskond | |
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| Kasutaja pidevautentimine Ja PETMISE VÄHENDAMINE VEEBITESTIDES Tallinna Tehnikaülikooli küberkaitse magistriprogrammi sisseastumisTESTI näitel | |
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Autorideklaratsioon

Kinnitan, et olen koostanud antud lõputöö iseseisvalt ning seda ei ole kellegi teise poolt varem kaitsmisele esitatud. Kõik töö koostamisel kasutatud teiste autorite tööd, olulised seisukohad, kirjandusallikatest ja mujalt pärinevad andmed on töös viidatud.

Autor: Eva Maria Veitmaa

Annotatsioon

Lõputöö on kirjutatud keeles ning sisaldab teksti leheküljel, peatükki, joonist, tabelit.

Abstract

The thesis is in and contains pages of text, chapters, figures, tables.

Lühendite ja mõistete sõnastik

|  |  |
| --- | --- |
| Brauser | Ka veebilehitseja, veebisirvija. HTML-dokumentide lugemist võimaldav programm [1]. |
| Buutima | *To boot*. Alglaadima. „Operatsioonisüsteemi arvuti põhimälusse laadima ja käivitama.“ [1] |
| DevOps | „Koostööd soodustav kultuuriline ja operatiivne mudel, mis tagab IT suure jõudluse ärieesmärkide saavutamiseks.“ [2] |
| EER | *Equal error rate*, veamäär[3]. Olukord, mil valepositiivsete ja valenegatiivsete väärtuste esinemine on võrdne [4]. |
| Ekraanipilt | *Screenshot*. Kuvariekraanil parasjagu näha oleva visuaalse informatsiooni salvestamise tulem graafikafaili kujul [1]. |
| Elektroentsefalograafia (EEG) | Ajutegevuse mõõtmine, peaaju bioelektrilise aktiivsuse registreerimine läbi naha, kolju ja ajukestade [5], [6], [7] |
| Elektrokardiograafia (EKG) | Südame elektrilise aktiivuse mõõtmine [3], [8], [7] |
| Funktsiooniklahv | *Function key*. „Kuum klahv“. Spetsiaalset ülesannet täitvad klahvid arvutiklaviatuuril (F1 kuni F12) [1] |
| IP-aadress | Internetiaadress, võrgus asuva arvuti või muu seadme identifikaator [1] |
| Kuvahõive | Arvutiekraanil toimuvast koopia tegemine operatsioonisüsteemi vahendite, rakenduse või välise seadme (nt kaamera) abil, *screen capture* [1]. |
| LFW | *Labeled Faces in the Wild*, enamasti professionaalsete fotograafide poolt pildistatud kuulsuste fotode andmebaas [9] |
| LMS | *Learning management system*, veebipõhine õppekeskkond, õppeinfosüsteem?. Keskkond, mis võimaldab hallata veebipõhiseid kursuseid, õppematerjale, õppureid ja tulemusi. [10] |
| LTI | *Learning Tools Interoperability*, IMS Global Learning Consortiumi standard õppekeskkondade ja väliste rakenduste ning vahendite ühendamiseks [11] |
| Matkimisrünne, kehastusrünne | Isiku esinemine kellegi teisena, identiteedi jagamine (*impersonation*) [12]. Isik A väidab end olevat isik B. |
| MOOC | *Massive open online course*, vaba juurdepääsuga e-kursus, tasuta veebipõhine kursus [13], [14] |
| Muutmälu | Suvapöördusmälu, RAM (*random access memory*). Arvuti keskne mäluseade, millesse salvestatud info kustub toite välja lülitamisel [1]. |
| NIR | *Near infrared*, lähi-infrapunane (valgus) [15], [16] |
| Pääsmik | *Security token*. „Füüsiline volitustõend, näiteks kiipkaart või USB kaudu ühendatav seadis.“ [17] |
| RAM-ketas | Kirjutatav ketas [1] |
| Ründe-kaitsepuu | Ründe tulemuseni viivate võimalike teede esitus koos ründeid tõrjuvate kaitsemeetmetega. [18] |
| Ründepuu | Ründe tulemuseni viivate võimalike teede formaliseeritud esitus. Nõrkustest võimalike ründetulemusteni viivate teede formaliseeritud esitus. [17] |
| Spektroskoopia | Aine ja kiirguse interaktsiooni (neeldumine, emissioon, hajumine) uuriv teadusharu [5], [19] |
| Taasesitusrünne | Andmete salvestamine ja taasesitamine näiteks kasutajatuvastussüsteemi petmiseks [17] |
| TTÜ | Tallinna Tehnikaülikool |
| Variisik | Isik, kelle nime all tegutseb keegi teine (*impostor*) [20]. Matkimis- ehk kehastusründe ehk identiteedi jagamise läbiviija. Isik A, kes väidab end olevat isik B. |
| Võõrküpsis | *Third party cookie* [21]. Lühike andmeplokk, mille salvestab kasutaja arvutisse mõni muu veebileht kui see, mida hetkel külastatakse [1]. |
| Veebilehitseja | Ka brauser, veebisirvija. HTML-dokumentide lugemist võimaldav programm [1]. |

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# Sissejuhatus

# Tallinna Tehnikaülikooli küberkaitse õppekava

Alates 2009. aastast pakub Tallinna Tehnikaülikool tudengitele võimalust õppida küberkaitse magistriõppes [22]. Käesoleva õppekavaversiooni kood on IVCM09/18, maht 120 EAP-d jaotatuna nominaalõppeaja nelja semestri peale ning seda pakutakse koostöös Tartu Ülikooliga [23]. Õppetöö toimub inglise keeles ning juurdepääsu tingimusteks on muuhulgas varasem kõrgharidus või töökogemus info- ja kommunikatsioonitehnoloogia valdkonnas.

Õppekava eesmärgiks on valmistada tudengeid ette süvaõppeks küberkaitse, digitaalse ekspertiisi või krüptograafia peaerialal ning arendada nii teoreetilisi teadmisi kui ka praktilisi oskusi, tegelemaks infosüsteemide turvalisuse, digitaalsete tõendusmaterjalide ning arvuti turvaintsidentidega. Võimalik on läheneda nii tehnoloogilise, teoreetilise kui ka organisatoorse nurga alt.

Küberkaitse magistriprogrammi sisseastumisprotsessi käigus tuleb Tallinna Tehnikaülikoolile esitada oma Curriculum Vitae ja motivatsioonikiri, sooritada simulatsiooniülesandeid sisaldav veebipõhine test ehk sisseastumiseksam ning läbida vestlus [24]. Magistriõppes on lävendipõhine vastuvõtt, mis tähendab, et vastu võetakse kõik kandidaadid, kes ületavad eelnevalt ülikooli poolt seatud punktisumma, ning õppekoht küberkaitse erialal on tagatud, kui vastuvõtuprotsessis on saadud vähemalt seitse punkti kümnest [23].

## Sisseastumistesti keskkond

Tallinna Tehnikaülikooli küberkaitse magistriprogrammi tehniline test sooritatakse RangeForce [25] virtuaalses keskkonnas. Tegemist on pilvepõhise platvormiga, mille eesmärgiks on jäljendada tõsielulisi ründestsenaariume, võimaldades küberturbe spetsialistidel, arendajatel ja DevOps valdkonna töötajatel enda oskusi pidevalt proovile panna.

Pärast ülikoolile sisseastumisavalduse esitamist edastatakse kandidaadile unikaalne promokood, millega Rangeforce keskkonnale ligi pääseb. Sisseastumistest koosneb neljast RangeForce’i virtuaalmasinas sooritatavast laborist (vt Joonis 1), millest on soovituslik läbida vähemalt üks. Sisseastumistestil käsiteldavad teemad hõlmavad muuhulgas näiteks Linux CLI, Apache, HTTPS ja SQLi valdkondi. Laborite sooritamise ajal pakub RangeForce keskkond kandidaatidele juhiseid ja näpunäiteid, hõlbustamaks ülesannete lahendamist.

![A screenshot of a social media post

Description generated with very high confidence](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDoRXhpZgAATU0AKgAAAAgABAE7AAIAAAAKAAAISodpAAQAAAABAAAIVJydAAEAAAAUAAAQzOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEV2YSBNYXJpYQAABZADAAIAAAAUAAAQopAEAAIAAAAUAAAQtpKRAAIAAAADNzAAAJKSAAIAAAADNzAAAOocAAcAAAgMAAAIlgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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Joonis . RangeForce tutvustav labor.

Kuna test on veebipõhine ja selle sooritamiseks ei pea Tallinna Tehnikaülikooli füüsiliselt kohale tulema, kaasneb kandideerimisprotsessil matkimis- ehk kehastusründe (*impersonation*) oht. Nimelt võib avalduse esitanud kandidaat otsustada, et konsulteerib testi tegemise ajal mõne endast targema isikuga või laseb kogunisti terve testi sooritada variisikul ehk kellelgi teisel kui endal. Viimast juhtu ongi antud töös nimetatud ka kehastus- ehk matkimisründeks. Kuna test sooritatakse enne vestlusvooru, on kahtluste esinemise korral võimalik testi kohta täpsustavaid kontrollküsimusi esitada vestlusel.

# Senised saavutused

Alljärgnevalt on välja toodud mõningad lahendused veebipõhise õppe ja eksamite rikkumatuse tagamiseks nii akadeemilises kui kommertsvaldkonnas.

## Akadeemilised uuringud/lahendused/ideed/ettepanekud/katsetused

Fask et al leiab, et traditsioonilist järelevalvega klassiruumis toimuvat eksamit sooritavatel tudengitel on eelis nende ees, kes teevad testi koduses keskkonnas, kuna puudub võimalus vaatlejalt täpsustavaid küsimusi küsida ja esineda võib probleeme arvuti või internetiühendusega [26]. Lisaks järeldavad nii Fask et al kui ka Harmon et Lambrinos [27] oma tulemustest ka seda, et veebipõhistel järelevalveta eksamitel esineb eksamikorra rikkumist (*cheating*) sagedamini. Alessio et al uurimise tulemused viitavad sellele, et järelevalvega veebipõhiste eksamite sooritajate tulemus on halvem kui ilma järelevalveta eksaminandidel [28]. Eksamikorra rikkumist võib vähendada keelatud tegevuste ja nendega kaasnevate tagajärgede kuvamine hoiatusena vahetult enne eksami algust [21]

Sindre et Vegendla loetlevad veebipõhiste eksamitele spetsiifilised probleemid kui kehastusrünne (*impersonation*), koostöö või kõrvalistelt isikutelt abi saamine, plagiaat, keelatud abimaterjalide (kalkulaator, raamatud) kasutamine, sooritusaja rikkumine (varem alustamine, hiljem lõpetamine), tehniliste probleemide kohta valetamine aja juurde võitmise eesmärgil, eksamiküsimuste salvestamine ja hilisem edastamine teistele eksaminandidele [29].

Bawarith et al kasutab petmise tuvastamiseks sõrmejäljega sisselogimist, peab arvet aja üle, mil kandidaat eksami ajal arvutiekraani ees ei viibi ning kandidaadi silmade fookuspunkti, välistamaks kaamera vaateväljast eemale jäävate kõrvaliste materjalide kasutamist [30]. Peaasendit ja vastamise ajalist viidet on potentsiaalse petmise vastase kaitsemeetmena uurinud Chuang et al [31].

Rosen et Carr eksperimenteerivad USB-ga arvuti külge ühenduva kaameraga robotiga, mis filmib suvalise mustri alusel eksamikeskkonda ja arvutiekraani, kuid keskendub heli tekkimisel tolle allikale, ja kontrollivad eksaminandi identiteeti kõrvatuvastuse alusel [32], samas kui Atoum et al kasutavad sülearvuti ja peakaamerat ning mikrofoni, et teha kindlaks kasutaja isik ning tuvastada eksamikeskkonnas kõrvalise teksti, heli ning telefoni olemasolu [33].

Fenu et al keskendub veebipõhise õppe puhul kehastusrünndele ja kasutab selle vältimiseks multibiomeetrilist pidevtuvastussüsteemi (vt Peatükk 5.2), mille eesmärk on vältida ülesande- ja seadmespetsiifilisust, see tähendab, et tuvastus töötab erinevat tüüpi ülesannetega (tekstivastus, valikvastus, suuline vastus jm) ja nii süle- ja lauaarvutite kui ka tahvlite ja mobiiltelefonide korral [34]. Nende lahendus kontrollib nägu, häält, puudet, hiirt ja klahvivajutusi, tuvastamaks kasutajat kogu kursuse vältel.

Multimodaalsusele keskendub ka Traoré et al, kes soovitab pidevtuvastuseks kombineerida näotuvastust, hiire kasutusviisi ja trükkimise dünaamikat, põhinedes kasutajal juba olemas oleval riistvaral (veebikaamera, hiir, klaviatuur) [12]. Infot antud biomeetriliste näitajate kohta kogutakse eksami jooksul passiivselt ehk kasutajat häirimata ning lubamatu käitumise (matkimisrünne, eksaminandi lahkumine kaamera vaateväljast, mitu isikut eksamit lahendamas) esinemisel teavitati eksami järelevalve teostajat. Nende pakutud raamistik leidis kasutust ExamShield platvormi arenduses.

Clarke et al kirjeldab enda kaitsesüsteemi ideed kui õppesüsteemi kohal asuvat vihmavarju, mis pakub võimalust kasutajat tuvastada ja jälgida ilma õppesüsteemi tegevusse sekkumiseta [35]. Nende e-Invigilator’i puhul puuduks vajadus alla laadida lisatarkvara, kuna tegemist on brauseripõhise lahendusega. Oma töös implementeerisid nad vaid näotuvastuse osa.

Amigud et al keskendub sisuloome alusel kasutaja tuvastamisele [36]. Nimelt leitakse, et ühe ja sama tekstilise ülesande lahendamiseks kasutatav kirjutamisstiil, -mustrid ja sõnavara erinevad inimeste lõikes ning nende alusel on võimalik isikut tuvastada. Amigud et al andmeanalüüsil põhinev lahendus tuvastas teksti autori 93-protsendilise täpsusega. Võrdluseks, et kursuste juhendajad suutsid tudengite kirjastiili alusel pettust avastada vaid 12% juhtudest.

Mothukuri et al on oluliseks pidanud lukustusbrauseri olemasolu (vt Peatükk 5.5), mis takistab ligipääsu keelatud programmidele ja funktsioonidele, ja näo- ning hääletuvastuse rakendamist, tuvastamaks ruumis esinevaid kõrvalisi isikuid [37].

Carlisle et Baird pakuvad välja spetsiaalse CD-lt buutiva lukustussüsteemi, milles on asendatud tavapärane failide avamise ja sulgemise dialoogaken [38]. Failid salvestatakse krüpteeritult kasutaja arvuti kõvakettale, millele testi sooritamise ajal ligi ei pääse, ja krüpteerimata kujul RAM-kettale, kust kasutaja neid avada saab. Blokeeritud on võrguühendus, USB-pesad, paremklikk ja kuigi lukustussüsteemi saab jooksutada virtuaalmasinas, märgistatakse sellisel juhul salvestatud failid ning neid ei krüpteerita. Väliselt kettalt buutivat autentimisvõtmega testsüsteemi soovitab ka Rosen et Carr [32].

Mõningad teaduslikud uuringud on näidetena eraldi välja toodud ka vastavate kaitsemeetmete juures (vt Peatükk 5).

## Kommertslahendused

Eksisteerivad laiatarbelised eksami järelevalve lahendused jagunevad üldpildis neljaks.

Kõige traditsioonilisem neist on eksami sooritamine kontrollitud keskkonnas, nagu eksamikeskus või eraldatud ruum ülikoolis. Testi tegemise ajal jälgivad kandidaate vaatlejad, kelle ülesandeks on tuvastada ebaausat käitumist, nagu spikerdamine, kaaslasega konsulteerimine või keelatud abivahendite kasutamine. Kuna vaatlejateks on enamasti sama asutuse töötajad, võib kindel olla, et nad on kursis spetsiifiliste reeglitega, mida asutus eksamite korral rakendab, nagu näiteks sobiv riietus või lubatud abivahendid [39]. Kahjuks aga ei suuda ülikoolid enamasti palgata piisaval hulgal vaatlejaid, et tuvastada kõik ebaausa käitumise katsed. Veebipõhiste kursuste korral muudaks kohustus füüsiliselt eksamikeskusesse tulla eksaminandide elu keerulisemaks ja MOOCide ehk vaba juurdepääsuga e-kursuste puhul oleks taoline nõue mõeldamatu.

Reaalajas võrgujärelevalve korral kontrollitakse kandidaati kogu testi lahendamise vältel. Vaatluse all on nii ekraanil toimuv kui ka eksami sooritaja ise näiteks ekraanijagamistarkvara, mikrofoni ja veebikaamera pildi vahendusel [40]. Järelevalvet teostab ideaalis isik, kes on läbinud vastava koolituse ja oskab tähele panna petmisele viitavaid märke. Kuigi taoline lahendus võimaldab eksamit sooritada asukohast sõltumatult, eeldab see siiski ühise aja kokku leppimist ja sobiva kvalifikatsiooniga vaatleja palkamist ning on sellest tulenevalt järgnevatega võrreldes majanduslikult kulukam ja raskesti vajadusele kohandatav, kuna üks vaatleja suudab korraga jälgida vaid nelja kuni kümmet õpilast [41].Ka siin ei pruugi vaatleja märgata kõiki rikkumisi, kuid kuna kandidaat ei tea, millisel ajahetkel just teda jälgitakse, võib väheneda soov petta [39]. Mõned firmad pakuvad eksami järelevalve teenust koos enda poolsete vaatlejatega, kuid erinevalt kohaliku akadeemilise personali kaasamisest protsessi ei saa firmade puhul kindel olla, et vaatlejad on usaldusväärsed ja kursis konkreetse asutuse eksamireeglistiku ja akadeemiliste tavadega. Reaalajas võrgujärelevalvet pakub näiteks Pearson VUE [42]. Valikvastustega testi puhul saab tulemuse teada kohe.

Salvestatava järelevalve puhul lindistatakse heli- ja videoseadme abil eksaminandi ennast ja tema arvutiekraanil olevat pilti, mida vaatleja hiljem mitmekordsel kiirendusel kontrollib, et analüüsida hetki, mil võis aset leida pettus [43]. Kuigi antud lahendus ei nõua, et eksami sooritamine ja järelevalve toimuksid samaaegselt, ning võimaldab sooritust vaadata tempokamalt kui reaalajas, on kontroll siiski jätkuvalt seotud inimfaktoriga, mille usaldusväärsuses ei saa kindel olla juhul, kui tegemist pole vastavalt kvalifitseeritud personaliga. Samuti tekib viivitus eksamitulemuste teada saamisel, kuna eelnevalt tuleb kindlaks teha, et tudeng ei ole reegleid rikkunud. Positiivse poole pealt säilib eksamist digitaalne tõend, mis hõlbustab hilisemate apellatsioonide lahendamist. Antud valdkonnas on pikalt tegutsenud Software Secure firma [44].

Hetkel on kõige tehnilisem lahendus automaatne järelevalve, mis sarnaselt eelnevatele eeldab ekraani ja kandidaadi lindistamist, kuid lisaks sellele analüüsib süsteem jooksvalt heli ja videopildi andmevoogu, tuvastamaks kahtlustäratavat ja ebasobivat käitumist [43]. Erinevate algoritmide abil kontrollitakse ruumi valgustust, kaadris asuvaid kahtlaseid objekte, eksamineeritava keskendumist ekraanile, taustaheli ja -pilti. Näotuvastus kindlustab, et testi sooritab üks ja sama isik. Ohukohad märgistatakse ning kuigi teoreetiliselt peaks kogu järelevalvega hakkama saama automaatsüsteem, on neid soovi korral võimalik hiljem ise üle kontrollida. Inimesest vaatleja puudumine tähendab, et ei eksisteeri piirangut eksami sooritamise ajale ja kohale, ning kogu süsteem muutub paremini vajadusele kohandatavaks, võimaldades kandidaatidele seada lisatingimusi näiteks piiratud operatsioonide, kindla IP-aadresside vahemiku või teiste rakenduste avamise takistamise näol. Kõiki kandidaate koheldakse võrdselt, sest vaatlejaks on algoritm, mitte inimene [39]. Soovi korral on eksaminande ka testi sooritamise ajal võimalik teavitada potentsiaalsest rikkumisest, tuletamaks meelde reeglistikku ja võimaldamaks selle alusel käitumist parandada. Kahjuks ei ole olemasolevad automaatsed järelevalvesüsteemid veel piisavalt head, et osutuda majanduslikult kasumlikuks. Mõned olukorrad märgitakse valepositiivselt ning mõned tagasihoidlikumad spikerdamiskatsed jäävad arvutil märkamata, mis tähendab, et lõpliku kontrolli peab jätkuvalt teostama inimene. Ühe Software Secure kliendi puhul märgiti 100 000-st toimunud eksamist potentsiaalseid pettuseid sisaldavaks 2425, millest reaalne rikkumine toimus 613 eksamil [41]. See tähendab, et algoritm tuvastas rikkumisi vääralt 75% juhtudest. Samuti ei saa automaatset eksamijärelevalvet kasutada, kui lubatud on abimaterjalid, sest süsteem ei tee vahet õpikul ja muudel märkmetel. Täisautomaatse järelevalvega testimist pakub firma Talview [45].

Nagu näha, eksisteerib mitmeid erinevaid eksami järelevalveks loodud süsteeme, millest mõned eeldavad lisariistvara olemasolu või nõuavad suuremal määral inimese osalust (vt Tabel 1). Seetõttu saab väita, et turul on juba lai valik kommertslahendusi, mille seast on võimalik endale sobivaim leida, selle asemel, et seda ise luua.

Tabel . Järelevalve kommertslahenduste võrdlus.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Kandidaadi jälgimine | Ekraanipildi jälgimine | Vajalik lisaseade | Integreeritav olemasoleva keskkonnaga | Vajalik inimvaatleja olemasolu |
| Talview Remote Proctor | x | x |  | x |  |
| Remote Proctor PRO | (väline lisaseade) | (väline lisaseade) | x | x | x |
| RPNow | x | x |  | x | x |
| Pearson VUE | x | x |  |  | x |
|  |  |  |  |  |  |

Alljärgnevalt on kirjeldatud igast eelpool mainitud kategooriast vähemalt üht järelevalvelahendust.

### Talview - Remote Proctor/Proview

Talview on Indiast alguse saanud firma, mis on keskendunud nii tööle kui ülikooli kandideerimise protsessi sujuvamaks ja veebipõhisemaks muutmisele [46].

Proview järelevalvesüsteem võimaldab vältida spikerdamist ja kontrollitavaks kehastamist ja lubab kokku hoida testide administreerimiskuludelt [45]. Salvestatakse eksamitegija ekraanil toimuvat ning ümbruses olevat heli ja videot. Süsteem kindlustab, et kandidaat keskendub testi tegemise ajal ekraanile, ruumis on piisavalt valge, taustal pole kahtlasi esemeid ega heli. Sisse logivat kasutajat autenditakse isikut tõendava dokumendi alusel näotuvastusega ning sama funktsionaalsust kasutatakse, kontrollimaks, et kandidaat ei vahetu testi tegemise ajal ehk eksamit teeb kogu protsessi vältel üks ja sama isik. Algoritm tuvastab võimalikud eksamikorra rikkumised ja teavitab nendest jooksvalt testi tegijat, võimaldades tollel parandada oma niinimetatud terviklikkuse või aususe skoori (*integrity score*), mis on alustades 100 punkti, aga kahaneb iga rikkumisega [47]. Testi sooritamise jooksul kogutud info edastatakse krüpteeritult põhjaliku logina vaatlejale, Proview firma ise videoid ei näe. Iga tudengi kohta, kelle aususe skoor on alla eelnevalt administraatori poolt määratud piiri, esitatakse foto autentimisprotsessist, taustamüra ja ekraanil toimuva kokkuvõte, suvalisel hetkel tehtud pildid ekraanist ja kandidaadi näost ning video eksamiprotsessist, mida on vaatlejal hiljem võimalik 60-kordse kiirusega järele vaadata, et teha kindlaks, kas protseduurireegleid ka tegelikult eirati. Piisava punktisumma korral antud andmeid vaatlejale ei edastata, mis tähendab ühtlasi privaatsemat kogemust iga ausa testitegija jaoks. Korraga on võimalik ühel ekraanil jälgida kuni 64 kandidaati [48].

Kuna Proview on oma olemuselt Javascripti skript, on seda võimalik integreerida ükskõik millise testimissüsteemi või veebilehega, toetades seega ka testi sooritamist mobiilseadmetes. Kandidaatidel puudub vajadus eraldiseisvate rakenduste või veebipluginate allalaadimise järele ning eksami sooritamise aeg ja koht ei ole välise vaatleja poolt piiratud, kuigi soovi korral on testi administraatoril võimalik kandidaate reaalajas jälgida. Proview ei piirdu vaid eksamite ajal tudengite isiku kontrollimisega, vaid võimaldab kogu kursuse vältel kindlaks teha, et ülesandeid lahendab üks ja sama tudeng. Lisaks eksamite vaatlusele ja õppetööle saab seda kasutada ka veebipõhiste intervjuude või muu suhtluse kontrollimiseks.

Miinimumnõuded Proview kasutamiseks hõlmavad vähemalt 640x480 eraldusvõimega veebikaamera, mikrofoni, Chrome või Firefox veebilehitseja olemasolu [47]. Proview toetab operatsioonisüsteeme alates Windows Vistast ja Mac OS X 10.5. Edukaks kasutamiseks peab interneti allalaadimiskiirus olema vähemalt 768 kbit/s ja üleslaadimiskiirus 384 kbit/s ning läbilaskevõime minimaalselt 256 kbit/s, kuigi soovituslik on 512 kbit/s. Vajalik on 1024 MB vaba mälu (RAM). Nõuetele vastavust kontrollitakse eraldi riistvaratesti abil, mille kestus on vähem kui 90 sekundit.

Lisaks täielikult automatiseeritud testimisjärelevalvele pakub firma ka Talview Proctor Engine’il põhinevat täielikku eksamikeskkonda, võimaldades muuseas kontrollida lugemist, kuulamist, kirjutamist, grammatikat, programmeerimisoskust [49]. Talview lahendusi kasutab näiteks Cambridge English Language Assessment [50].

### Software Secure - Remote Proctor PRO

Software Secure alustas järelevalve pakkumist tark- ja riistvara ühislahendusest, võimaldamaks kontrollida kaugõppe eksamitel toimuvat. Lahenduse põhiobjektiks oli seadeldis Remote Proctor PRO, mis koosnes 360-kraadi kaamerast, mikrofonist ja sõrmejäljelugejast [51].

Esiteks sisenes eksaminand oma õppekeskkonda (näiteks Moodle) [52]. Seejärel tuvastati arvutiga ühendatud Remote Proctor PRO seadme abil kandidaadi isik, võrreldes hetkebiomeetriat kursusega liitumisel registreeritud sõrmejälje ja näopildiga. Kui autentimine ebaõnnestus või seadeldis polnud arvutiga korrektselt ühendatud, keelati eksamil osalemine. Kui kasutaja oli edukalt tuvastatud, käivitus testimisprogramm Securexam, mis võimaldas eksami sooritamise ajal kasutada ainult õppekeskkonda ja blokeeris kogu ülejäänud funktsionaalsuse, kaasa arvatud ligipääsu failidele, internetile ja muudele rakendustele.

Testi tegemise ajal lindistas Remote Proctor PRO seadeldis muutusi ruumis aset leidvas liikumises ja helis. Kogutud andmed saadeti internetiühenduse kaudu Software Secure serverisse, kust neid vaatasid hiljem veebiliidese vahendusel üle Software Secure palgatud tunnustatud spetsialistid, kelle ülesandeks oli tuvastada eksamikorra rikkumisi, nagu kõrvaliste materjalide või abi kasutamine. Videosalvestis ja ülevaade eksamisooritusest koos potentsiaalsete pettushetkedega edastati asutusele, kes langetas lõpliku otsuse kandidaadi reeglite vastu rikkumise kohta.

Kui eksaminandi internetiühendus katkes eksami sooritamise ajal või polnud piisavalt kvaliteetne videofailide edastamiseks, üritas Remote Proctor PRO tarkvara faile edastada iga kord, kui eksamitegija arvuti uuesti käivitati. Remote Proctor PRO 360-kraadi kaamera ja sõrmejäljelugejaga lisaseadet Software Secure lehel enam ei müüda [53], aga seda on võimalik osta näiteks eBayst või Amazonist [54]. Aastal 2010 oli õpilastele seadme maksumus 200 $ ja järelevalvetarkvara hind 30 $ semestris [55], mistõttu oli tegemist üsna kalli lahendusega. Küll aga saab seadet kasutada korduvalt, st mitme isiku autentimiseks, mistõttu võis pärast kasutust selle edasi müüa või seda ülikoolidelt rentida.

### PSI - Remote Proctor Now

Alates aastast 2017. kuuluvad Software Secure firma ja nende lahendused PSI Services LLC omandisse, laiendades seni tööjõu kvalifikatsiooni kontrollimisele keskendunud firma pädevusala ka akadeemilisele poolele [56]. Hetkel kasutusel olev järelevalvelahendus Remote Proctor Now (RPNow) ei kasuta kandidaatide jälgimiseks enam välist seadeldist, vaid kandidaadi internetiühendusega arvutit, veebikaamerat ja mikrofoni, ning on täielikult veebi- ja pilvepõhine. Platvorm on LTI toe olemasolul seotav ükskõik millise õppekeskkonnaga (näiteks Moodle [57]), mis tähendab, et eksamiparoolid, -ajad, tulemused ja muu õppeinfo on automaatselt sünkroniseeritud, vähendades vigade tekke ohtu andmete ümber kandmisel. Tänu sellele võimaldab RPNow hõlpsalt õppekeskkonnas loodud arvutipõhistele eksamitele järelevalvet lisada ja tulemusi hallata.

Õppejõud või eksameid administreeriv isik saab endale harjumuspärases õppekeskkonnas luua eksami ning seejärel RPNow integreeritud keskkonnas seadistada, kui kaua eksam kestab, kas antud eksamile on vaja järelevalvet, millised on eksamil lubatud rakendused, veebilehed ja lisamaterjalid [58], [44], [59].

Eksaminand peab esmalt alla laadima Flash-i kasutava RPNow Secure Browser veebilehitseja, mis kontrollib käivitudes veebikaamera, mikrofoni ja piisavalt kiire internetiühenduse (üleslaadimiskiirusega 125 kbit/s) olemasolu ja et arvutiga ei oleks ühendatud välist ekraani. Sobiva eksami valimisele järgneb kandidaadi autentimine, mille käigus peab tegema foto nii kandidaadist endast kui ka tema isikut tõendavast dokumendist (pass, ID-kaart) ning lindistama video ümbritsevast ruumist, veendumaks, et läheduses pole keelatud materjale või kõrvalisi isikuid. Kui autentimine on edukas, suunatakse eksaminand läbi RPNow veebilehitseja asutuse õppekeskkonda (Moodle), kus küsitakse eksami salasõna, mille RPNow sisestab krüpteeritult tudengi nägemata, takistamaks testi sooritamist otse õppekeskkonnas väljaspool RPNow platvormi. Testi tegemise jooksul lindistatakse kandidaadi arvutiekraanil ja ruumis toimuvat heli ja videopilti. Kui kandidaat üritab käivitada rakendust, mille testi administraator on eelnevalt keelanud, takistab RPNow programmi avamist ja kuvab hoiatusakna.

Eksamilindistust kontrollivad pärast testi sooritamise lõppu PSI poolt kvalifitseeritud vaatlejad, kes märgistavad lindistuses esinevad eksimused eksami haldaja (õppejõu, administraatori) poolt määratud eksamikorra vastu, nagu näiteks lubamata materjalide kasutamine, keelatud veebilehtede külastamine või eksaminandi isiku vahetumine. Kui vähemalt kaks vaatlejat on sooritusele hinnangu andnud, kuvatakse eksami haldajale õppekeskkonna PSNow-ga integreeritud lehel soorituste analüüs koos täieliku eksamivideoga, märgistatud rikkumisolukordade ja autentimisinfoga iga tudengi kohta individuaalselt.

PSI lahendusi kasutavad muuhulgas edX MicroMasters, Ivy Tech Community College, Clemson University, Purdue University [60].

### Pearson VUE

Lisaks ametlikes eksamikeskuses testimisele pakub Pearson VUE ka veebipõhist testimist, ilma et peaks kartma eksamireeglite rikkumist. Pearson VUE lahenduse puhul kasutatakse reaalajas võrgujärelevalvet [61]. Eksami sooritamiseks tuleb eelnevalt registreeruda ja kokku lepitud ajal testi lahendamist alustada. Eksaminande jälgivad veebikaamera ja Pearson VUE Secure Browser veebilehitseja vahendusel Pearson VUE poolt sertifitseeritud vaatlejad, kelle ülesandeks on tuvastada protseduurireeglite rikkumisi [42].

Enne eksami algust luuakse ühendus tervitajaga (*greeter*), kelle ülesandeks on isikut tõendava dokumendi alusel tuvastada kandidaat, korrata üle reeglistik, teha kindlaks veebikaamera ja mikrofoni korrektne töötamine, teostada videokaamera vahendusel põhjalik kontroll testimiskeskkonna nõuetele vastavuse kohta: et ruumis ei viibiks kõrvalisi isikuid, et keskkond oleks piisavalt valgustatud, et keelatud abimaterjale, kaasa arvatud spikrid, lisamonitorid, -arvutid, maalid või postrid seintel, poleks nähtaval või riiete ja juuste vahele peidetud [62]. Kui kandidaat on autenditud ja protokolli vastu eksimisi ei tuvastatud, luuakse ühendus vaatlejaga (*proctor*), kellega saab tehniliste probleemide ilmnemisel vestlusakna kaudu ühendust võtta. Eksam võidakse koheselt kuulutada mittesooritatuks, kui kandidaat lahkub toast, väljub kaadrist või kui ruumi siseneb kõrvalisi isikuid.

Pearson VUE kasutamiseks peab olemas olema veebilehitseja (Internet Explorer 9 või uuem, Microsoft Edge, Chrome, Firefox, Safari), väline või sisseehitatud mikrofon ja veebikaamera eraldusvõimega vähemalt 640x480 [62]. Eksami ajal on lubatud kõrvaklappide kasutamine. Toetatud on operatsioonisüsteemid alates Windows 7 ja Mac OS X 10.8. Lairiba internetiühenduse alla- ja üleslaadimiskiirus peab olema 512 kbit/s, Pearson VUE ise soovitab kaabliühenduse kasutamist. Arvuti ja lisatarvikute tehnilistele nõuetele vastavust on võimalik kontrollida ükskõik millal enne eksami alustamist.

Pearson VUE võimaldab soovi korral eksamit läbi viia ka ilma järelevalveta, võimaldades kandidaadil testi sooritada ajaliselt kellestki teisest sõltumata [61]. Pearson VUE reaalajas vaatlemise lahenduse abil testib kandidaate näiteks Microsoft [62].

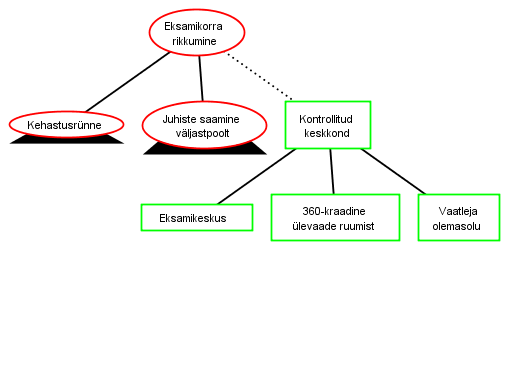
# Ründe-kaitsepuu / löögi-ohjepuu

Võimalikke ründeid RangeForce keskkonnas ja kaitseid rünnete vastu on kirjeldatud ründe-kaitsepuu (*attack-defence tree*) abil. Ründe-kaitsepuu on edasiarendus ründepuust (*attack tree*), mida on defineeritud kui ründe tulemuseni viivate teede formaliseeritud esitust (näiteks graafi või puu kujul) [17]. Ründepuu puhul tähistab puu juur (*root*) ründaja lõppeesmärki (*goal*), iga tipu ehk sõlme (*node*) järglased (*descendant*) viitavad alameesmärkidele (*sub-goal*), mis on tolles sõlmes oleva ründe läbi viimiseks vaja saavutada, ning puu järglasteta sõlmed ehk lehed (*leaves*) kirjeldavad ründaja tegevusi [63]. Ründepuu on väga hea meetod süsteemi turvalisuse analüüsimiseks, kuid erinevalt ründe-kaitsepuust ei võta ta arvesse võimalikke kaitsemeetmeid rünnete takistamiseks ning nende mõju rünnetele.

Ründe-kaitsepuus lisatud kaitsemeetmed võimaldavad jälgida ründaja ja süsteemi kaitsja vahelist suhet ning selle arengut [18]. Ründe-kaitsepuu koosneb kaht liiki sõlmedest: ründe- ja kaitsesõlmed. Igal tipul võib sarnaselt ründepuule olla üks või mitu sama liiki järglast ehk alameesmärki. Lisaks võib sõlmel olla ka üks vastasliiki järglane ehk vastumeede. Niisiis võib ühel ründetipul järglasteks olla mitu rünnet defineerivat sõlme ning üks kaitsemeetme sõlm, mille järglasteks võib omakorda olla mitu kaitset kirjeldavat tippu ning üks ründesõlm, mis vastava kaitse nurjab. Tipu järglaste vahelised seosed võivad olla disjunktiivsed, mille puhul sõlme eesmärk saavutatakse ühe sama tüüpi järglase eesmärgi saavutamisel, või konjunktiivsed, mille korral sõlme eesmärk saavutatakse kõigi samaliigiliste järglaste eesmärkide saavutamisel. Kaitse-ründepuud võib vaadelda kui mängu või võistlust ründaja ja süsteemi kaitsja vahel.

Käesolevas töös on ründe-kaitsepuu loomisel kasutatud ADTool tarkvara versiooni 2.2.2 [64]. Ründe-kaitsepuu on oma suurusest tulenevalt esitatud mitme joonise peale jaotatult. Punased ovaalsed tipud tähistavad ründeid ja rohelised nelinurgad kaitsemeetmeid. Joonisel tipu kohal asuv must kolmnurk viitab tipu vanemale ning tipu all asuv must riba tipu lastele, mis on joonisel peidetud. Kaht eriliigilist sõlme ühendab katkendjoon ning samaliigilisi sõlmi pidevjoon. Antud peatükk keskendub peamiselt potentsiaalsetele rünnetele, kaitsemeetmeid on laiemalt kirjeldatud peatükis 5 leheküljel 34.

RangeForce keskkonnas sisseastumistesti sooritamine jaguneb eksamikorra rikkumise valdkonnas üldpildis kaheks (vt Joonis 2). Üheks ohuks on kehastusrünne ehk olukord, kus kandidaat laseb sisseastumistesti osaliselt või kogu ulatuses sooritada variisikul ehk kellelgi teisel kui ta ise, kuid võimalik on ka välise abi kasutamine ülesande lahendamist hõlbustavate juhiste saamiseks.



Joonis . Eksamikorra rikkumine ründepuuna.

Mõlema ründe esinemise ohtu aitaks vältida või vähemalt vähendada testi sooritamine kontrollitud keskkonnas (vt Peatükk 5.1). Kodustes tingimustes sooritatava eksami (nagu küberkaitse eriala sisseastumistest) korral on täielikult kontrollitud keskkonna loomine keeruline, kui mitte võimatu, kuid ruumist 360-kraadise ülevaate nõudmine võib petmise ohtu kindlasti vähendada.

## Kehastusrünne

Kehastusründe kaitsemeetmeks oleks isikutuvastuse rakendamine. Isiku tuvastamise ehk autentimise võib üldpildis jaotada kaheks. Üheks protsessiks on isiku identifitseerimine ehk esitatavate andmete võrdlemine iga andmebaasis oleva isiku andmetega, leidmaks esitatud andmetele vastavat isikut [65]. Antud juhul on tegemist üks-mitu (1:N) seosega, kus ühe komplekti esitatud andmete puhul käiakse läbi mitu isikut, kuni leitakse vaste.

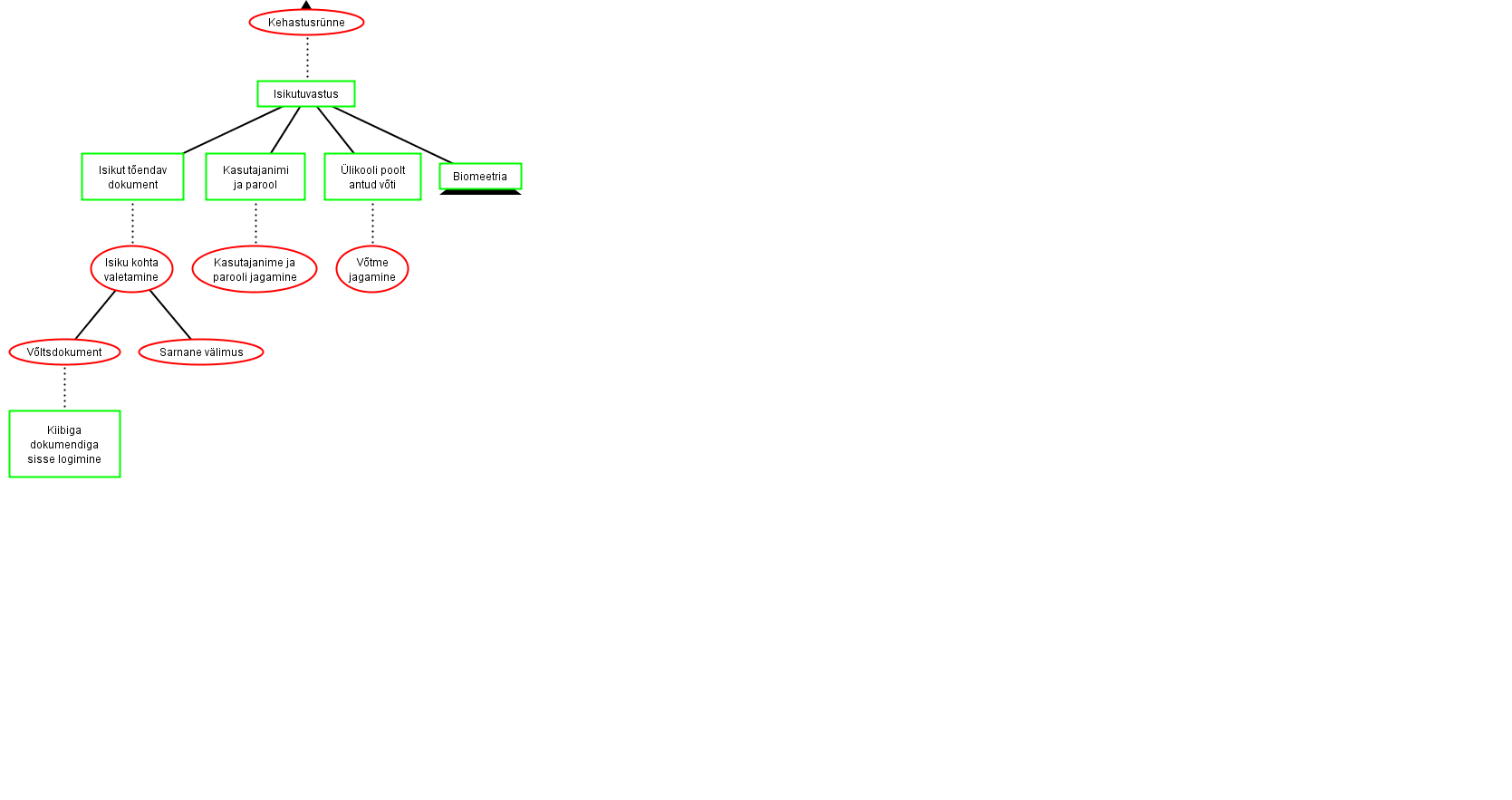
Teine protsess on isiku verifitseerimine, mille käigus üritatakse aru saada, kas andmed esitav isik on see, keda ta väidab end olevat [66]. Sellisel juhul võrreldakse isiku esitatud parameetreid konkreetse andmebaasis oleva isiku andmetega ehk teostatakse üks-üks (1:1) võrdlus. Tulemuseks on tõeväärtus vastavalt sellele, kas esitatud parameetrid vastavad andmebaasis sama isiku kohta käivatele varasemalt teada olevatele parameetritele või mitte.[67]

Eelnevast tulenevalt võib autentimist ehk kasutaja tuvastamist defineerida kui õigel ajahetkel õigete privileegidega õigele isikule õige ligipääsu võimaldamist [65].

Autentimist võib jaotada selle alusel, milliste faktorite järgi isikut tuvastatakse. Selleks võib olla midagi, mida kasutaja teab (salasõna, PIN-kood, turvaküsimuse vastus), mida kasutaja omab (ID-kaart, kiipkaart) või mis iseloomustab kasutajat ennast ehk biomeetria [68], [37], kusjuures viimane jaguneb veel omakorda füüsiliseks (nägu, sõrmejälg, silmaiiris) ja käitumuslikuks (trükkimisstiil, allkiri, kõnnak) biomeetriaks [69]   
(vt Joonis 4). Kui füüsiline biomeetria on enamasti muutumatu ilma kehamodifikatsioonideta, siis käitumine võib aja jooksul muutuda kasvõi kogemuste kogunemise ja süsteemiga harjumise [70], väsimuse või asendi [71] tõttu. Turvalisem on loomulikult mitme teguri kombinatsiooni nõudmine ehk multimodaalne süsteem.

Küberturvalisuse sisseastumistesti arvesse võttes võiks isiku tuvastamiseks kaaluda nelja varianti (vt Joonis 3, lk 26). Üheks neist oleks eksaminandi isiku kindlaks tegemine ametliku isikut tõendava dokumendi abil. Selleks võib kõrvutada dokumendifotot ja kandidaadi nägu (vt Peatükk 5.2.1). Antud meetod töötaks nii näost-näkku kohtumisel kui ka veebipõhise testi puhul, paludes viimase korral dokument kas sisse skannida või fotojäädvustuse tegemise eesmärgil veebikaamera ees hoida. Küll aga ei ole kumbki kaitstud dokumendi võltsimise vastu. Videokaadrist või skannitud fotolt on raske hästi järele tehtud riikliku dokumendi ehtsust kontrollida, eriti ainult visuaalse vaatluse käigus. Eesti näiteks pakub sellele lahendust kiibiga varustatud ID-kaardiga sisse logimise näol.

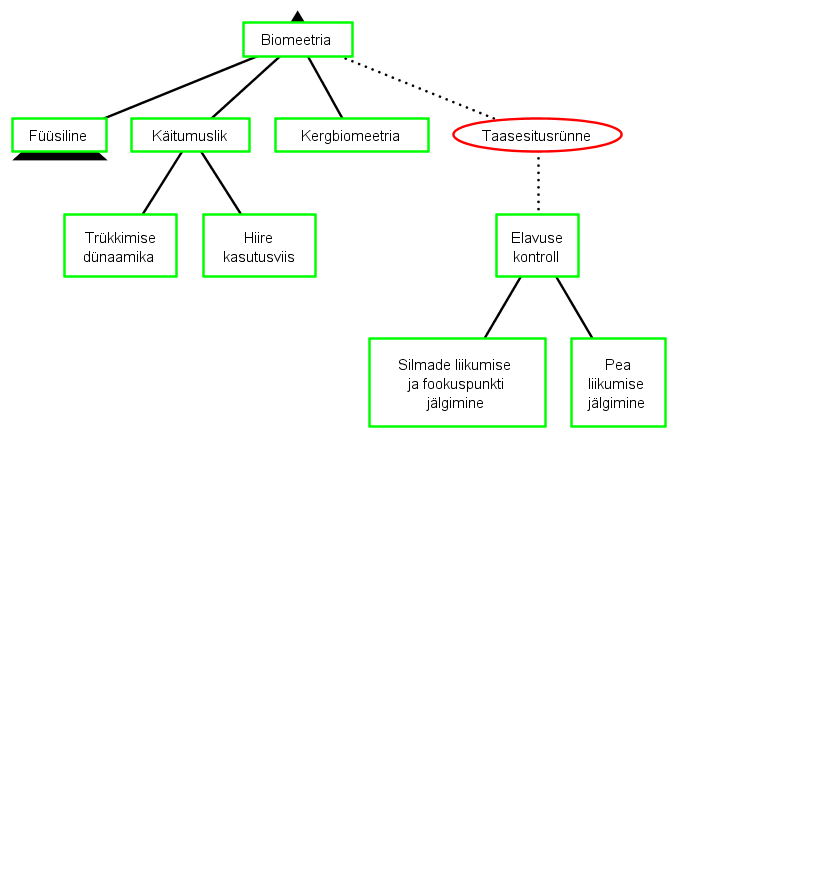
Lisaks võltsdokumendi esitamisele saab isikut tõendava dokumendiga kandidaati tuvastades pettust sooritada ka siis, kui variisik ja tegelik kandidaat on välimuselt sarnased (vt Joonis 3). Selline olukord võib tekkida näiteks ühe munaraku mitmikute korral või välimust abivahenditega (meik, parukas, võltsnäokarvad) muutes.



Joonis . Isikutuvastus.

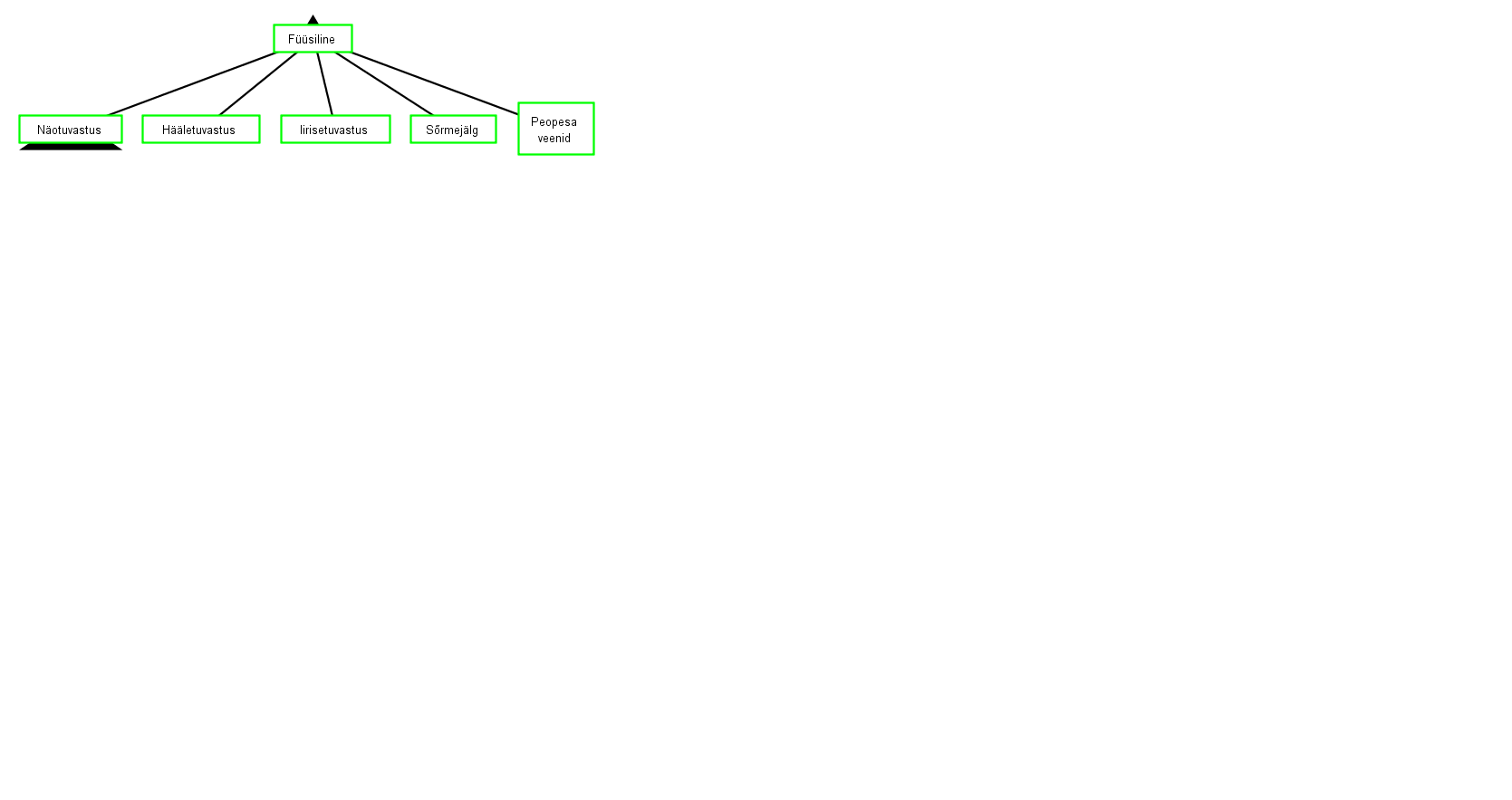
Teiseks isiku tuvastamise meetmeks oleks paluda kasutajal sisse logida millegagi, mida ta teab või millegagi, mida ta omab (vt Joonis 3). Eksaminandi enda seadistatud kasutajanimi ja hästi valitud parool (ka salasõna) võib olla kaitseks juhul, kui konto omanik ei soovi, et keegi sellele ligi pääseks, kuid sisseastumistesti puhul kehastusrünnet läbi viies võib kandidaat oma isikuga seotud autentimisinfot meelsasti variisikuga jagada. Sama kehtib ka siis, kui ülikool saadaks igale sisseastujale teda identifitseeriva unikaalse võtme või pääsmiku (näiteks kiipkaart või USB-ga ühendatav seade), millega kasutajat tuvastada.

Biomeetriat kui kasutaja tuvastamist tema olemuse järgi saab omakorda jaotada füüsiliseks, käitumuslikuks ning kergbiomeetriaks (vt Joonis 4). Kõik need on tundlikud taasesitusründele (*replay attack*). See tähendab, et biomeetrilisi näitajaid on võimalik mingil kujul (video, foto, helilindistus, sõrmejälg jmt) salvestada ja kopeerida originaalkasutajat salaja või avalikult jälgides või lindistades. Kui võltsitud karakteristikuid hiljem uuesti tuvastussüsteemile esitades saavutatakse keskkonnale ligipääs, ongi tegemist taasesitusründega. Selle vältimiseks tuleks kontrollida süsteemile esitatava biomeetrilise karakteristiku elavust, näiteks peaasendi või silmade fookuspunkti reageerimine ekraanil kuvatavale stiimulile (vt Peatükk 5.3, lk 48) või kehasoojuse ja muude elavusnäitajate, nagu pulss ja elektrijuhtivus, esinemist. Kuna RangeForce keskkonnas sisseastumistesti sooritajatelt ei saa eeldada eririistvara (pulsikella) olemasolu, langeb see alamkategooria kaitsemeetmete hulgast antud töö probleemi arvesse võttes välja.



Joonis . Biomeetria.

Isikutuvastuseks saab kasutada füüsilisi ja käitumuslikke karakteristikuid, nagu näiteks kasutaja nägu, hääl, silmaiiris, sõrmejälg, peopesa veenimuster (vt Joonis 5, lk 28) või trükkimise dünaamika ja hiire kasutusviis (vt Joonis 4). Neid võib omakorda toetada kergbiomeetriaga, mis põhineb inimkeha eristatavate, kuid mitte individualiseerivate tunnuste (sugu, juuksevärv, riidevärv, armid jmt) võrdlemises [17]. Nendest kõige lihtsam on taasesitada kergbiomeetriat. Selleks võivad variisik ja tegelik kandidaat kanda ühte tooni riideid, parukat või meiki. Kõige keerulisem on täpselt jäljendada käitumist. Sageli ei pööra kasutaja ise teadlikult oma tegevusstiilile tähelepanu, mistõttu vajab käitumusliku biomeetria taasesitamine teise inimese poolt põhjalikku jälgimist, lindistamist ja selgeks õppimist. Kõiki eelpool mainitud biomeetrilisi näitajaid on lähemalt kirjeldatud töö peatükis 5.2.



Joonis . Füüsilise biomeetria kaitsemeetmete jagunemine vms.

Füüsilise biomeetria baasil isiku autentimine on tõenäoliselt kõige lihtsam näotuvastuse abil, kuna seda saab teostada ka tavalist veebikaamerat kasutades. Nõudes kandidaadilt testi sooritamist veebikaamera ees, on kogu protsessi jooksul võimalik jälgida tema nägu ning teha kindlaks isiku vahetumine. Samas võib tekkida olukord, kus näotuvastust teostav kaamera on suunatud kandidaadi poole, kuid selle vaateväljast eemal lahendab sisseastumistesti sellegipoolest variisik (vt Joonis 6). Kuna inimese näoilme kipub sisseastumistesti sooritades ja YouTube’ist videoid vaadates erinema, võiks miimika jälgimine anda vihjeid selle kohta, kas näotuvastuse subjekt tegeleb parasjagu ülesande lahendamisega või mitte.

A close up of text on a white background

Description generated with high confidence

Joonis . Näotuvastusega kaasnevad ründed.

Ka silmade liikumise ja fookuspunkti vastavus kursori liikumisele, ekraanile tekkivatele elemenditele ja testis toimuvale võib anda vihjeid selle kohta, kas kaamera ees viibiv isik on testi lahendamas ise või jälgib sooritust lisaekraani vahendusel (vt Joonis 6). Eeldatavasti vaatab tegevust ise sooritav isik esmalt silmadega nupule, mida vajutada soovib, ning alles pärast silmadega nupule keskendumist liigutab sinna ka kursori. Kuna lisaekraanilt toimuvat jälgiv isik ei tea, mida tegelik testi sooritaja teha kavatseb, tekib pilgu ja hiireliikumise vahel ebakõla. Et vähendada näoilme ja fookuspunkti abil näotuvastussüsteemi petmist, tasub lisaekraani kasutamine keelata (vt Peatükk 5.4, lk 50).

## Välise abi kasutamine

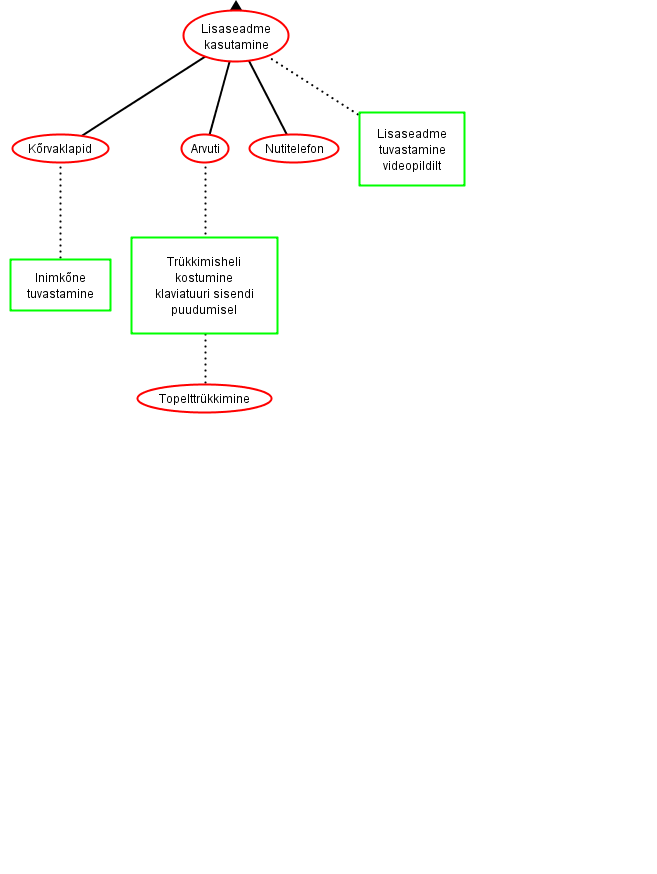
Kuigi küberkaitse sisseastumistest on mõeldud iseseisvaks lahendamiseks, puudub hetkel kontroll selle üle, kas kandidaat leiab lahenduskäigud omapead või kasutab selleks välist abi, näiteks otsib sisseastumistesti täielikku lahenduskäiku internetist[[1]](#footnote-1) kasutades selleks lisaseadet või sama arvutit, millega eksamit sooritab, konsulteerib ruumis või eemal viibiva kõrvalise isikuga vahetult või suhtlusprogrammi abil või kasutab ülesande edastamiseks ja lahendatud saamiseks ekraanijagamisprogrammi abi (vt Joonis 7).

A close up of a logo

Description generated with high confidence

Joonis . Ründed välise abi saamiseks.

Lisaseadme all on mõeldud kellegi teise edastatavate juhiste kuulamist (juhtmevabade) kõrvaklappide abil ja mobiili või teise arvuti sisseastumistesti lahenduskäigu otsimise või juhiste saamise eesmärgil kasutamist (vt Joonis 8). Kuna testi lahendamiseks kasutatava arvuti kaitsesüsteem ei laiene teistele ruumis viibivatele seadmetele, on ainsaks võimaluseks nende tuvastamine heli- ja videopildi kaasabil (vt Peatükid 5.6 ja 5.7). Näiteks kõrvaklappide abil juhiseid saades võib esineda hetk, kus kandidaat palub saadud juhist täpsustada. Tol hetkel saab ruumi heli kuulates tuvastada inimkõne esinemist, mis võib viidata eksamikorra rikkumisele.



Joonis . Võimalikud lisaseadmed ja meetmed nende tuvastamiseks.

Klaviatuuriga lisaseadet kasutades on ruumis kosta trükkimisheli, kuid puudub sisend arvutil, milles testi sooritatakse. Seda saaks omakorda rünnata, trükkides samaaegselt ka testimismasinal. Sellise olukorra avastamine on juba keerulisem, aga võimalik, näiteks analüüsides, kas konsooli kirjutatud tekst oli lihtsalt suvaliste tähtmärkide jada, mis hiljem ilma käivitamata kustutati, või mitte. Puutetundlike vahendite korral mehaanilisele seadmele spetsiifiline trükkimisheli puudub.

Kui eelpool oli esile toodud ruumis viibivalt kõrvaliselt isikult abi saamist, siis juhtnööride edastamiseks ei pea ilmtingimata samas ruumis viibima, vaid kasutada võib ka suhtlusprogramme (vt Joonis 9). Selleks on oluline eksaminandil väliste ülesandesse mitte puutuvate rakenduste kasutamist ja kõrvaliste veebilehekülgede külastamist blokeerida (vt Peatükk 5.5, lk 51).

A close up of a logo

Description generated with very high confidence

Joonis . Kaitsed suhtlusprogrammi kasutamise takistamiseks.

Välise lisakaamera abil on võimalik edastada videopilti arvutiekraanil toimuvast, et selle baasil kelleltki teiselt juhiseid saada (vt Joonis 10). Ekraanijagamisprogrammid võimaldavad lisaks ekraanist reaalajas video edastamisele arvutis toimuvat lausa teisest seadmest juhtida. Koos näotuvastusega sarnaneb see rünne lisaekraani kasutamisele, kuid on ennetatav, kasutades lukusturbrauserit ehk programmi, mis takistab kasutajal teiste rakenduste avamist (vt Peatükk 5.5, lk 51).

A close up of a piece of paper

Description generated with high confidence

Joonis . Ekraani jagamise rünne.

Siiski pole ka lukustusbrauseri kasutamine ideaalne kaitsemeede, kuna ei takista välise lisaseadme kasutamist, suhtlus- ja ekraanijagamisrakenduste alla laadimist ja käivitamist RangeForce virtuaalmasinas ning olukorda, kus lukustusprogramm käivitatakse lokaalses masinas jooksma pandud virtuaalmasinas (vt Joonis 11). Viimase puhul on kõrvalised rakendused blokeeritud virtuaalmasinas, aga lokaalses masinas, milles virtuaalmasin käivitati, saab kõiki rakendusi sellest hoolimata kasutada.

A close up of a piece of paper

Description generated with high confidence

Joonis . Lukustusbrauseri kasutamisega kaasnevad ohud.

Nagu eelnevast näha, on võimalusi eksamikorra rikkumiseks hulgaliselt. Järgnevalt on lähemalt vaadeldud võimalikke kaitsemeetmeid RangeForce keskkonnas toimuva sisseastumistesti rünnete ennetamiseks ja tuvastamiseks.

# Kaitsemeetmed

Järgnevalt on esile toodud mõningad kaitsemeetmed, vähendamaks identiteedi jagamise ohtu ehk seda, et kandidaat laseb testi enda isiku alt sooritada kellelgi teisel, ja lähtudes tingimusest, et testimiskeskkonnaks on RangeForce, kus abimaterjalide kasutamine on lubatud.

## Kontrollitud keskkond

Kõige kindlam viis, veendumaks, et kandidaat teeb eksamit ise ja protseduurireeglitele vastavalt, on nõuda testi sooritamist kontrollitud järelevalvega ruumis, nagu näiteks eksamikeskus, milles kasutatavaid lisaseadmeid, nagu näiteks arvutid, on eelnevalt võimalik seadistada täpselt nii, nagu korraldaja heaks kiidab. Kontrollitud keskkonna puhul saab veenduda, et seintel või laudadel pole keelatud lisamaterjale nagu valemid või spikrid, valgustus on sobiv, eksaminandid istuvad üksteisest piisavalt kaugel ja saavad segamatult töötada.

Kontrollitud keskkonnas on enamasti ka vähemalt üks vaatleja. Riigieksamite puhul on selleks näiteks eksamikomisjon ja Sihtasutus Innove poolt sertifitseeritud välisvaatleja [72], ülikoolide puhul enamasti õppejõud ja nende abilised, kelle ülesandeks on jälgida, et ei eksitaks akadeemiliste tavade vastu, näiteks keelatud abimaterjale kasutades või kaastudengiga konsulteerides. Osaliselt kontrollitud keskkonda võib tekitada ka virtuaaleksamitel, kasutades selleks näiteks arvutiekraanist ning ruumist 360-kraadi ulatuses videopilti edastavat kaamerat, kuid sellisel juhul ei saa välistada abimaterjalide peitmist laua alla või muu varjava objekti taha ega ka seadmete modifitseerimist kandidaadi poolt.

Teiseks aspektiks on isikutuvastus. Statsionaarõppe puhul tunnevad õpetajad ja õppejõud enamasti oma õpilasi nägupidi, mis takistab kellelgi teisel kandidaadina esinemist. Küll aga ei ole kehastusrünne välistatud eraldiseisvate eksamikeskuste ja selliste kursuste puhul, kus õpe toimub e-keskkonnas, aga eksami tegemiseks peab füüsiliselt kohale tulema. Kehastusründe all võib kannatada ka TTÜ küberkaitse sisseastumistest.

## Isiku pidev autentimine

Kui kontrollitud keskkonna puhul on raske ette kujutada, et eksaminandid poole eksami pealt vahetuvad, et kellelgi teisel enda eest test ära teha lasta, siis koduses keskkonnas on seda juba märksa keerulisem jälgida. Staatilised süsteemid, kus kasutaja isikut kontrollitakse ainult sisselogimisel, ei ole veebitestide korral piisavalt turvalised ka juhul, kui kasutajat ei kontrollita mitte ainult kasutajanime ja parooli kombinatsiooni, vaid ka biomeetriliste näitajate, nagu sõrmejälg, näotuvastus või silmaiirise skaneerimine, alusel [73].

Kasutaja autenditakse sessiooni algul sisse logimise hetkel ning sessiooni vältel verifitseeritakse kasutajat pidevalt või periooditi [71].

Üks potentsiaalne meetod kontrollimaks, et testi tegemise vältel kandidaat ei vahetu, on testitegija isiku pidev tuvastamine (ka pidevtuvastus, pidevautentimine, *continuous authentication*), mille võib jaotada kaheks - aktiivne ja passiivne autentimine [73]. Aktiivse autentimise puhul võidakse kasutajalt teatud ajaperioodi tagant või mõne tegevuse järel nõuda spetsiifilise ülesande, mis kinnitaks tema isikut, täitmist, näiteks parooli sisestamine, silmaiirise skaneerimine, teatud fraasi trükkimine või lausumine. Passiivse pidevautentimise puhul kogutakse andmeid taustal ilma kasutaja töövoogu segamata, muutes süsteemi kasutajasõbralikumaks ja eelistatumaks kontekstis, kus kasutaja keskendumine on põhiline.

, ~~kuid võttes aluseks eelpool püstitatud tingimused, tasub RangeForce süsteemi baasil läbi viidava sisseastumistesti puhul keskenduda mitme kasutajat kirjeldava biomeetrilise või käitumusliku atribuudi kontrollimisele~~.

Kasutaja pidevtuvastus ei tööta, kui kogu protsessi vältel sooritab tegevusi (registreerumine, sisselogimine, testi lahendamine) variisik ja puudub võimalus kontrollida kandidaadi tegelikku isikut, näiteks valitsuse andmebaasis leiduvate dokumentide põhjal. Eestis pakub isiku identiteedi kinnitamiseks ideaalset võimalust ID-kaart, mis on riigipoolseks kinnituseks, et antud isiku nimi ja nägu kuuluvad kokku. Sellisel juhul on võimalik andmebaasist saadud nime ja näo kombinatsiooni võrrelda testitegija omaga ja veenduda, kas isik on see, keda ta väidab end olevat. Kahjuks või õnneks ei ole need andmed avalikult kätte saadavad, teostamaks visuaalset kontrolli dokumendifoto alusel, küll aga on võimalik sisselogimist ID-kaardi tarkvara kaudu kontrollida. Kui eksisteerib varasemalt kasutajaga toimunud interaktioon, võib kasutajat tuvastada varasemal suhtlusel põhinevate turvaküsimuste alusel.

Kuna kõige raskem on muuta kasutajat ennast iseloomustavaid faktoreid, on järgnevalt analüüsitud mõningaid biomeetrilisi ja käitumuslikke näitajaid, mille alusel võiks RangeForce süsteemi kasutajat testi tegemise ajal korduvalt tuvastada.

### Näotuvastus

Kõige esimesena võiks tulla pähe visuaalne vaatlus arvutit kasutava isiku tuvastamiseks. Näotuvastus põhineb näo eristatavate tunnusjoonte ruumigeomeetria analüüsimisel [65]. Selle meetodi puhul määratakse, millised on vaadeldavad tunnused, mida erinevate piltide puhul võrrelda, nagu näiteks ninaotsa, suu, silmade vahemaa, ega jälgita kasutaja muid muutuda võivaid tunnuseid, nagu näoilmed, -karvad või juuksed. Üheks oluliseks väljakutseks ja tuvastuse esimeseks sammuks on inimnäo eraldamine ümbritsevast keskkonnast/taustast ehk näoavastus.

**Saavutused.** Näotuvastusel kasutatakse näiteks närvivõrke ja masinõpet [74]. Aastal 2014 saavutas Facebook kombineeritud süva-närvivõrke kasutades DeepFace projekti raames kuulsuste fotosid sisaldaval andmestikul Labeled Faces in the Wild (LFW) tuvastustäpsuse 97.35% [9]. Edasiarendus DeepID3 küündis samal andmestikul lausa 99.53% täpsuseni [75], mis jääb siiski vaevu alla Google FaceNet’i 99.63 protsendist [76]. Võrdluseks, et inimene suudab nägusid tuvastada 97.5% täpsusega [9].

Näotuvastus eeldab kasutajalt veebikaamera olemasolu. Õnneks on nüüdisajal paljudel müügil olevatel sülearvutitel veebikaamera juba sisse ehitatud ja ka väliseid veebikaameraid on laialdaselt saadaval.

Näotuvastuse edukusel võivad rolli mängida mitmed kasutajast või keskkonnast tulenevad faktorid, nagu näiteks ruumi valgustus, peaasend või näos olevad lisaseadmed. Sobilik süsteem ei tohiks end lasta häirida prille kandvast kasutajast. Adekvaatne näotuvastus nõuab piisavat valgustust.

**Elavus.** Video ei ole tegelikult ei midagi muud, kui seeria järjestatud pilte, mistõttu saab näotuvastust edukalt kasutada ka videovoo puhul. Just video puhul on oluline kontrollida ka näo elavust, et vältida taasesitusrünnet ehk süsteemi petmist staatilise foto, eellindistatud video, 3D-mudeli [77] või -maski [78] esitamise abil. Staatilist fotot saab kontrollida, paludes kasutajal pead liigutada või silmi pilgutada. Video esitamise vältimiseks on võimalik kontrollida kasutaja fookuspunkti, kuvades suvalisse asukohta ekraanil mõne punkti, kuhu kasutaja vaatama peab, või paluda kasutajal suvalises järjekorras teatud suunas pead liigutada. Virtuaalreaalsustehnoloogia abil on võimalik fotode põhjal koostada ka juhitavat 3D-mudelit kasutaja näost, mida elavuskontrollide petmiseks kasutada [77]. Mobiilseadmete puhul saab elavuse kontrolliks lisaks kaamerale kasutada ka güroskoopi ja kiirendusmõõturit [79], kuid arvutite puhul tasub keskenduda fookuspunkti kontrollimisele, mida on lähemalt vaadeldud antud töö peatükis 5.3. Ekstreemsemaks võimaluseks oleks ka kasutaja emotsiooni ja reaktsiooni jälgimine, kuvades näiteks keset töövoogu ekraanile mõne ehmatava pildi või video. Too lahendus loomulikult häiriks kasutaja keskendumist ega ole seetõttu eelistatud. Xu et al on välja pakkunud mitmeid teisigi potentsiaalseid kaitsemeetodeid, nagu pulsist tekkiv perioodiline mikroerisus näotoonis või näo ootamatu valgustamine tava- või infrapunavalgusega, jälgides samal ajal, kas muutub ka esitatava kaadri valgustatus [77].

Kui näotuvastust kombineerida mõne muu ajutise näitaja analüüsimisega, on võimalik kasutajat tuvastada ka siis, kui ta istumisasend (poos) pole optimaalne või ta vaatab veebikaamerast kõrvale. Selleks saab kasutada näiteks riiete värvi jälgimist [80]. Sisse logides salvestatakse kasutaja näo all oleva piirkonna värv, mida hiljem biomeetriliste näitajate puudumisel uuesti kontrollitakse. Kui tuvastatakse kasutaja lahkumine arvutiekraani eest või muutus näojoontes ja/või riiete värvis, on alust arvata, et tegemist pole enam sama kasutajaga, misjärel süsteem lukustatakse. ~~Seetõttu ei ole antud lahendus sobilik inimesele, kes iga viie minuti tagant riideid vahetab :)~~

Traoré et al OpenCV-le toetuva algoritmi eesmärgiks oli veebikaamera kaudu ja näo järgi tuvastada rikkumisi veebipõhistel eksamitel [12]. Nende pidevautentimissüsteemi täpsus oli 100%, see tähendab, et süsteemil õnnestus alati tuvastada variisik. Näotuvastussüsteem lindistas eksamit, tundis ära ja verifitseeris kandidaati näo alusel ning teavitas vaatlejat, kui kandidaat lahkus eksami ajal arvuti eest, testi tegi variisik või testi lahendas mitu tudengit korraga. Probleeme põhjustas muutus testimiskeskkonnas, eriti valgustustingimustes. Näotuvastuse täpsus langes drastiliselt, kui muudeti laualambi asukohta või kustutati valgus.

Fayyoumi ja Zarradi välja pakutud lahendus võrdleb testile registreerumisel andmebaasi salvestatud fotot testi tegemise aegse veebikaamera videovooga [81]. Lisaks sellele tuvastatakse kahesekundiliste videolõikudega, kas kasutaja jälgib ekraani ja on keskendunud eksamiküsimustele vastamisele. Kui leitakse, et kasutaja tähelepanu on mujal ehk võib esineda olukord, kus eksaminand kasutab keelatud abimaterjale, hoiatatakse testitegijat testimiskeskkonna taustavärvi muutusega. Samamoodi teavitatakse kasutajat ka ebaõnnestunud pidevautentimisest. Kui teatud aja jooksul ei õnnestu kasutajat tuvastada, peatab süsteem töö ja palub asendit korrigeerida. Korduval ebaõnnestumisel eeldatakse, et toimub pettus. Võrgukoormuse vähendamiseks kasutab Fayyoumi ja Zarradi lahendus meetodit, kus 30 sekundi tagant tehtud kahe sekundi pikkusest videoklipist valitakse kliendipoolse rakenduse abil välja parima näoilme, eraldusvõime ja valgustustingimusega kaader, mis edastatakse analüüsimiseks serverile. ~~Peaasendi kui ühe kergema fookuspunkti määraja järgi on petmist tuvastatud varemgi [82].~~

**Baasfoto.** Näotuvastust kasutades on vaja algsel registreerumisel tehtud fotot, millega edaspidist videovoogu kõrvutada. Baasfoto puhul on oluline, et see pärineks võimalikult usaldusväärsest ja kontrollitavast allikast, sest vastasel juhul võib kandidaat võrdluseks esitada pildi variisikust, kes hiljem tema eest eksamit sooritab. Seega oleks sobiv näiteks kandidaadi riiklik isikut tõendav pildiga dokument, nagu ID-kaart või pass. Puhtalt visuaalsele vaatlusele toetudes ei saa muidugi lõplikult veenduda dokumendi autentsuses ning alati jääb alles kahtlus, et dokument on võltsitud, kuid seda probleemi ei saa kõrvaldada enne, kui dokumentide ehtsuse kinnitamiseks kasutatakse ühtset süsteemi, nagu see on Eesti ID-kaardi puhul. Üheks variandiks oleks eksaminandidelt nõuda Eesti e-residentsust, kuid e-residendiks hakkamine võtab aega, eeldab kohalikus riigis Eesti saatkonna või konsulaadi külastamist ning maksab 100 eurot [83], mistõttu ei ole see tõenäoliselt ainult sisseastumiseksami sooritamise eeltingimusena praktiline nõue.

Video baasil pidevautentimise puhul võib probleemiks osutuda ka kogutud andmete saatmine üle võrgu serveripoolele, kus toimub nende analüüs. Edukaks edastamiseks on vaja piisavalt kiiret internetiühendust. Harjumuspäraste failiedastusprotokollide puhul kasutatakse kaadrite pidevaks edastamiseks liiga palju kasutaja arvuti ressursse (protsessor, mälu), mille tagajärjeks võib olla ühenduse katkestamine, edastuse aeglustamine või veebilehitseja töötamise lõpetamine. Ühendusega seotud probleeme oleks võimalik vähendada, kui algoritm töötaks lokaalses masinas. ~~Ühekordse veebipõhise eksamisessiooni puhul oleks see mõeldav, sest vaja on tuvastada, et kogu protsessi, mis ei kesta enamasti kauem kui mõni tund, vältel on arvuti ees üks ja sama isik~~. Andmehulka saab vähendada, kui analüüsida videovoogu perioodiliselt ehk võtta vaatluse alla ainult teatud ajahulga taga tehtud kaader [12]. Eksami puhul on see lubatud eeldusel, et analüüsitavate kaadrite vahele jääv ajaperiood on piisavalt lühike, et takistada inimeste vahetumist või tuvastada kõrvalise isiku esinemine ekraani ees.

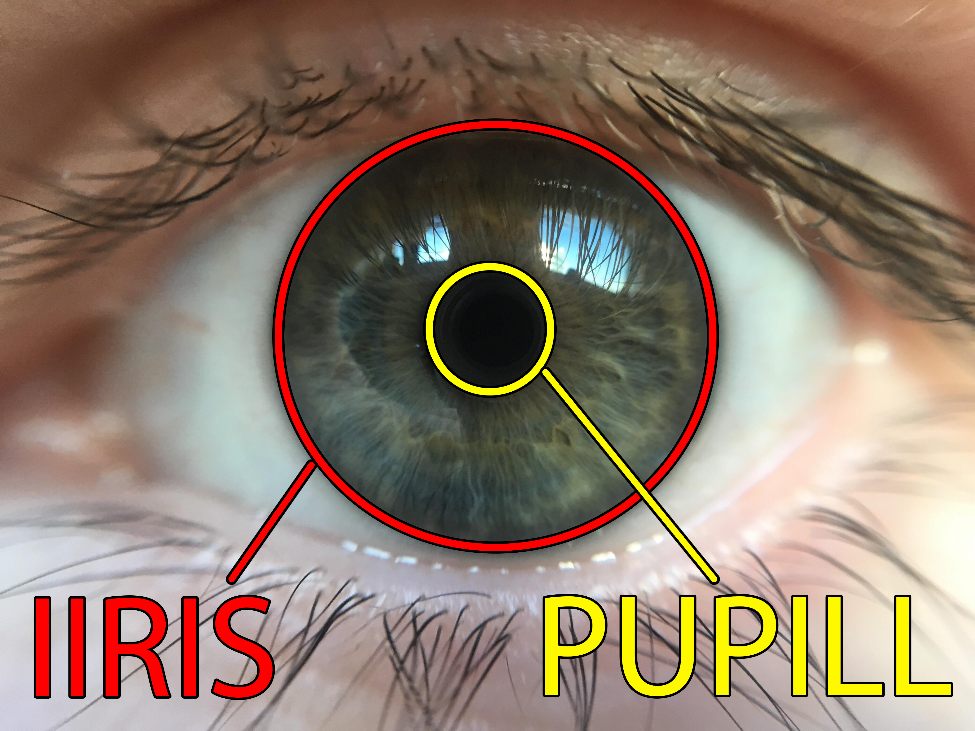
Isegi, kui eeldada, et sisseastumiseksami kaitsesüsteem teeb edukalt vahet kandidaadi ja variisiku näol, ei ole ainult näotuvastuse rakendamine piisav kaitsemeede. Nimelt oleks sellisel juhul võimalik tekitada olukord, kus veebikaamera on kogu eksami vältel suunatud kandidaadi poole, aga testi lahendab sellest hoolimata keegi teine, kes kaamera vaatevälja ei ulatu. Ohuks on ka juhiste edastamine kandidaadile *bluetooth*-kõrvaklappide kaudu, mis on võimalik, kui ei kontrollita, et kandidaadi kõrvad oleksid katmata.

### Hääletuvastus

Üheks autentimismeetodiks on hääletuvastus. Pidevautentimiseks saaks seda kasutada suuliste eksamite puhul, kuid kuna küberkaitse eriala sisseastumiseksam RangeForce keskkonnas ei sisalda suulist osa, ei saa seda antud kontekstis kasutada kandidaadi isiku kontrollimiseks, mistõttu ei ole käesolevas töös hääletuvastusele keskendutud.

Küll aga on võimalik tuvastada ümbritsevas ruumis olevat heli, et teha kindlaks, et keegi kandidaadile kõrvalt suulisi juhiseid ei edasta. Taustakõne keelamine töötab juhul, kui kandidaadil pole kombeks lahenduskäike iseendaga valjusti läbi arutada. Sisseastumiseksami puhul on vaikusenõue põhjendatud. Taustaheli analüüsist on räägitud käesoleva töö peatükis 5.6.

### Iirisetuvastus



Joonis . Silmaiiris ja pupill.

Iirisetuvastuseks nimetatakse biomeetrilist isikutuvastust, mis põhineb silma vikerkesta mustril [84]. Iiris on silma värviline osa pupilli vahetus ümbruses (Joonis 12), mille värvid võivad inimeseti korduda, kuid struktuur ja mustrid üldjuhul mitte, mistõttu pakub silmaiiris head võimalust kasutajate eristamiseks [85]. Vajalik on kvaliteetse kaamera olemasolu, et määrata küllaltki väikese iirise (diameetriga keskmiselt 11 mm) asukoht võimalikult täpselt. Enamasti kasutatakse selleks silma valgustamist infrapunase või lähi-infrapunase (*NIR - near infrared*) valgusega. Silmaiirise alusel kasutaja tuvastamine on kõige efektiivsem, kui iiris asub kaamerast maksimaalselt ühe meetri (1 m) kaugusel [15].

Kuna iirise korrektne tuvastamine nõuab kõrgekvaliteetset või eririistvaralist kaamerat ja kindlat vahemaad sensorist, ei ole see taolisel kujul sobilik kasutaja pidevtuvastamiseks RangeForce sisseastumistesti raames ning käesolevas töös sellele laiemalt ei keskenduta.

### Trükkimise dünaamika

Antud töös on sünonüümidena käsitletud termineid trükkimise dünaamika, klahvivajutuste dünaamika, trükkimisstiil.

Trükkimise dünaamika on hea meetod kasutaja tuvastamiseks, kuna ei nõua eririistvara, vaid tugineb klaviatuuri kui sisendseadme ja teatud klahvinuhi tarkvara olemasolule. Analüüsida saab nii klahvivajutuse kestust [86], erinevate klahvide vajutamise vahelist aega [87], trükkimisprotsessis esinevaid pause ja trükkimise tempot [88] kui ka seda, kas klahve vajutatakse eraldi või samaaegselt, mille erinevus tuleb esile suurtähti sisaldava fraasi puhul, kus võib kasutada nii Shift- kui CapsLock-klahvi (shift vs caps lock) [86].

Kasutajat saab (jooksvalt) tuvastada ka trükkimise visuaalsel või helilisel teel [89] või analüüsides klahvidele avaldatud survet [90] [91] - meetodid, mis nõuavad klaviatuurile ja kätele suunatud kaamerat käte asendi ja kuju jälgimiseks, mikrofoni klahvivajutustel tekkiva heli analüüsimiseks või vajutustugevuse kohta informatsiooni koguvat survetundlikku klaviatuuri. Võttes arvesse eeldust, et kasutajal on vaid üks veebikaamera, mis võib sülearvutite puhul olla integreeritud ja seega raskesti klaviatuurile suunatav, ja soovi kasutada ainult olemasolevat lihtsasti kätte saadavat riistvara, on surve, käte asendi ja trükkimise visuaalne analüüs antud töös kõrvale jäetud.

Kuna klahvivajutuste dünaamika puhul on tegemist käitumusliku biomeetriaga, on ründajal või variisikul seda äärmiselt raske imiteerida ka originaalkasutaja tegevuse vaatlemise tagajärjel [89]. Lisaks võib ajapikku kasutaja trükkimisstiilis esineda muutusi, mis on tingitud näiteks käte väsimisest pikaaegse kirjutamise tagajärel või oskuste kogunemisest [81] ja mis mõjutavad tuvastusprotsessi efektiivsust. Trükkimine võib ka sõltuda kasutatavast klaviatuurist ja selle harjumuspärasusest kasutajale [92].

Kasutaja korrektseks tuvastamiseks trükkimise baasil vajab süsteem eelnevat treenimist ja andmestikku [93]. Treenimisprotsess võib olla pikk ja keeruline [88], aga mida paremini koostatud algoritm, seda kiiremini tuvastatakse kasutaja vahetumine.

Trükkimisstiili saab kontrollida staatiliselt, näiteks parooli sisestamisel sisse logimise ajal. Eeldusel, et see protsess on varem korduvalt toimunud, on võimalik lisaks parooli korrektsusele käesoleva sisestuse trükkimisdünaamika andmeid võrrelda varasematega, et teha kindlaks, kas parooli sisestas sama isik, mis varem. USAs on võimalik küsimusi genereerida ka avalike andmete põhjal (nt eelmine postiindeks) [40]. Selline lahendus takistab kõrvalistel isikutel kontole ligi pääseda ka juhul, kui kasutaja parool ise on teada. Küll aga ei takista see kõrvaliste isikute ligipääsu juba alanud seansi korral [94]. Lisaks staatilisele tuvastusele on võimalik klahvivajutuste põhjal kasutajat autentida perioodiliselt [88], analüüsides trükkimist teatud hulga tähemärkide sisestamise või pausi esinemise järgselt, ja pidevalt [87]. Pidevtuvastuse puhul on oluline, et vale kasutaja tuvastatakse nii kiiresti kui võimalik ehk võimalikult väheste klahvivajutuste järel [69] ja et õiget kasutajat ei eemaldataks süsteemist esimese kõrvalekalde peale, vaid alles siis, kui usalduskvoot on langenud alla teatud piiri [69]. Bours et al töös oli selleks näiteks keskmiselt 182 tähtmärki [69]. Trükkimisstiili jälgimine on passiivne autentimisviis, kuna seda saab teostada ilma kasutajalt eraldi keskendumist nõudmata, ja protsess ei sega üldjuhul kasutaja tööjärge [88].

Mondal ja Bours olid ühed esimestest, kes analüüsisid ka ühe käega trükkimise tagajärjel tekkinud andmestikku ning kinnitasid püstitatud hüpoteesi, et ühe käega trükkimise tuvastuse edukus erineb suuresti mõlema käega trükkimise omast [87]. Seetõttu peaks süsteem arvesse võtma ka hetki, kus kasutaja sisestab teksti ajutiselt ainult ühe käega, ning ei tohiks kasutajat koheselt süsteemist välja visata.

Klahvivajutuste dünaamika salvestamiseks on parem töölauarakendus kui kergemini kasutatav ja arendatav veebipõhine lahendus, sest viimane sõltub suuresti platvormi tingimustest (veebilehitseja, RAM, protsessi prioriteet) ja ei tuvasta sageli funktsionaalseid klahve, nagu Enter, Control, Shift [92]. Töölauarapõhine rakendus võimaldab lisainfot koguda ka kursori liikumise ja süsteemiprotsesside kohta [92], laiendades kasutaja tuvastust ka hiire kasutusviisi arvelt.

Kuna RangeForce testid eeldavad käskude trükkimist virtuaalmasina terminalis, sobib kasutaja klahvivajutuste dünaamika analüüsimine eksaminandi identiteedi kontrollimiseks. Soovides suurendada analüüsitava trükiteksti hulka, võib kandidaadil paluda enne eksami algust ümber trükkida ette antud tekst näiteks akadeemilisest korrast kinni pidamise kohta või testi sooritamise ajaks keelata kopeerimise ja kleepimise operatsioonid [92], mis tähendab, et isegi, kui eksaminand leiab veebist sobiva käsu, peab ta selle käsitsi ümber kirjutama, suurendades analüüsitavate klahvivajutuste andmestikku, mis omakoda võimaldab kasutajat täpsemini tuvastada. Võrdlusandmestiku genereerimiseks ja kaitsesüsteemi treenimiseks võib süsteemi sisse logides paluda sisestada enamlevinuid terminalikäske, mis ka ülesannete lahendustes esinevad.

Klahvivajutuste kogumisel on oluline andmestiku privaatsuse tagamine, kuna kogutud andmed võivad sisaldada kasutajanimesid ja paroole või tundlikku infot kasutaja enda kohta [92]. Tundlikud andmed tuleks enne trükkimisinfo salvestamist sellest kindlasti eemaldada või loobuda andmestiku salvestamisest. Kuna RangeForce testi puhul on kirjutamisstiili analüüsimine oluline vaid sessiooni vältel, tuvastamaks kasutaja vahetumist, ega vaja loodetavasti hilisemat uurimist, puudub vajadus andmete salvestamiseks. Lisaks ei nõua RangeForce ülesanded kasutajalt oma personaalsete andmete sisestamist, mistõttu ei saa sisestatud teksti nimetada tundlikuid andmeid sisaldavaks.

Seega võiks sobilik stsenaarium olla analoogne Roth et al pakutuga [89], kus süsteem käivitub parooli sisestades ja salvestab sellest momendist alates 30 sekundi jooksul kasutaja klaviatuuri kasutust, mis muutub edaspidise võrdluse baasiks kogu sessiooni vältel. Kui kasutaja lahkub arvuti tagant pikemaks perioodiks, sessioon lõppeb ja biomeetriline võrdlusbaas kustutatakse. Mõistlik on analüüsida kahe või enama klahvivajutuse kombinatsioone, näiteks kuidas erineb ’chown’ ja ’touch’ käske sisestades klahvivajutuste ’c’ ja ’h’ kestus ja vajutuste vahel olev aeg, kuigi see võib eeldada nende korduvat trükkimist enrolment-faasis.

Küll aga ei piisa ainult trükkimisprotsessi jälgimisest, sest see lubaks konsulteerida mõne teise ruumis viibiva isikuga, sisestamaks terminali nende ette öeldud käske. Samuti ei ole variisiku tuvastamine ainult trükkimise baasil kohene ja võtab aega [89], kuna nõuab võrreldava andmestiku kogumist.

### Hiire kasutusviis

Teiseks laialdaselt levinud sisendseadmeks on arvutihiir ja puutepadi (*touch pad*). Hiire puhul saab jälgida näiteks kursori asukohta eksaanil, hiire liigutamise suunda, kiirust, kiirendust ja sujuvust, liikumisvahemaad pikslites ja pausi tegevuste vahel [95], nuppude vajutamist ning lahti laskmist ja rulliku (*mouse wheel*) kasutamist [94]. Klikkimisel saab eristada üksikvajutust, topelt-klikki ja lohistamist. Eririistvaralise puutepadja puhul on võimalik analüüsida ka vajutuse survetugevust.

Ka hiiredünaamika jälgimisel on vajalik õppeperiood, et tuvastada konkreetsele kasutajale iseloomulik hiirekasutus. Tegelikult on hiire abil kasutajat lihtsam tuvastada pidevautentimisel kui staatilisel autentimisel [96], kus kogutavaid andmeid on kordades vähem. Sharif et al [97] implementeerisid andmestiku kogumise klahvivajutuste analüüsimise ja värviakna abil, kus kasutaja kindlas järjekorras neljal värviruudul klikkima pidi. Sayed et al [96] on selle probleemi lahendamiseks välja pakkunud närvivõrkudel põhineva sisselogimissüsteemi, kus kasutaja tuvastatakse sisselogimise ajal joonistatava sümboli järgi. Nii võib hiirekasutust võrrelda ka allkirjaga, mis peaks igal kasutajal olema unikaalne. Taolist alternatiivi traditsioonilisele salasõnaga sisselogimisele pakub näiteks BioMetric Signature ID [98].

Käesoleva töö autoril on näiteks komme oma harjumuspärast hiirt seda kasutades aeg-ajalt hiirematilt korraks kergitada ja seejärel samasse kohta tagasi asetada, mis põhjustab kursori koha peal jõnksutamist ja võib seetõttu olla üheks kasutajale iseloomulikuks jooneks.

Rose et al leidis, et vertikaal- ja horisontaalsuunas liigutatakse hiirt tavaliselt sirgjooneliselt, samas kui diagonaalidel tekib pigem kaarjas joon, kusjuures kaardumise kraad ja suund on iga kasutaja puhul unikaalne, pakkudes seega võimalust isiku tuvastamiseks [70].

Feher et al on võimelised kasutajat tuvastama kõigest ühe hiiretoimingu järel (to check!! sounds fishy) [71], suurendades nii sissetungija avastamise kiirust. Nende testgrupp kasutas nii optilisi hiiri, puutepatju (*touch pad*) kui ka krihvleid (*stylus*).

Mondal et Bours’i jõudsid masinõppealgoritme kasutades pidevtuvastuse lahenduseni [95], mille eesmärgiks oli, et terve sessiooni vältel ei tuvastataks tõelist kasutajat väärana. Oma lahendust katsetasid nad andmestikul, mis oli genereeritud arvutit igapäevaselt ilma mingisuguste piiranguteta kasutavate inimeste käitumisest. Ka nende eesmärgiks oli tuvastada kasutaja kõigest ühe hiiretoiminguga, mistõttu ei saanud nad kasutada statistilisi tunnusjooni, vaid üht sündmust iseloomustavaid iseärasusi. Kasutati Bours’i välja mõeldud usaldusmudelit, mille kohaselt õige kasutaja puhul usaldustase tõuseb ja vale puhul langeb, kuni alla teatud piiri langemist süsteem lukustatakse.

BioCatch suurendab hiire kasutusviisi jälgimist erinevate kasutaja jaoks märkamatute kõrvalekalletega, nagu näiteks hetkeks hiire ekraanilt peitmine või hiire liikumisel kursori sihtpunktist kergelt kõrvale kallutamine, sundides nii kasutajat aktiivselt hiirt liigutama, et seda jälle ekraanilt leida, või oma liigutust korrigeerima [99]. Esimese meede on efektiivne kasutajatuvastusel ja teine välistab olukorra, kus tegevusi sooritab arvuti, mitte inimene.

Dünaamika jälgimisel võib takistusi osutada hiire tüüp. Mehaanilise hiire puhul, mis ei ole küll enam nii levinud, võib funktsionaalsust mõjutada liikuvate osade vahele takerduv lint, optilisel hiirel valgust peegeldav või läbipaistev aluspind. Mõne hiire puhul tekib raskusi kiirete liigutuste salvestamisega [71]. Sõltuvalt oma füüsilisest asukohast (kodu, kool, ühistransport) võib sülearvuti kasutaja sisendseadmena kasutada kas välist hiirt või arvutile sisse ehitatud lahendusi, nagu osutushoob (näpuhiir, pointing stick, TrackPoint) või puutepadi (touch pad), millest sõltuvalt kasutusviis erineb ja valmistab raskusi kasutaja profiili koostamisel. Küll aga võib eeldada, et sisseastumiseksami lahendamise ajal kasutaja oma sisendseadet liiga sageli ei muuda. Erandiks võivad olla vaid sülearvuti omanikud, kelle puhul esineb olukord, kus intensiivse trükkimisprotsessi ajal eelistatakse kiireks hiireliigutuseks pigem puutepatja või osutushooba kui sülearvuti kõrval asuvat arvutihiirt.

Hiiredünaamikat tasub pidevautentimise täpsuskindluse tõstmiseks kombineerida klahvivajutuste dünaamikaga (vt Peatükk 5.2.4) või silmade fookuspunkti analüüsimisega (vt Peatükk 5.3).

### Hiire kaasabil autentimine

Hiire abil autentimine ei pea tähendama vaid kasutaja hiireliigutuste jälgimist. Kuna arvutihiire sisse on võimalik integreerida mitmeid autentimistehnoloogilisi lisalahendusi, saab hiirt kasutades jälgida kasutaja käelt kogutavaid andmeid. Sim et al on kasutaja pidevtuvastamiseks välja pakkunud idee kasutada sõrmejäljelugejaga hiirt [100]. Koos näotuvastusega pakub see kaitset, kui kasutaja sirvib veebilehti või e-posti, kasutades kerimiseks hiirt, kuid kuna trükkimise ajal on käed klaviatuuril ja peaasend on tavakasutajal pigem suunatud alla, ei ole tol hetkel võimalik kasutajat edukalt tuvastada. Seetõttu ei ole ainult hiirel asuva sõrmejäljelugeja ja näotuvastuse abil kasutaja autentimine praktiline. Üheks võimaluseks oleks lisada trükkimisdünaamika analüüs.

Küll aga on tänapäeval sõrmejälge arvestatavalt lihtne võltsida kasvõi skänneri ja 3D-printeri abil. Teisalt, USA valitsusorganisatsiooni National Institute of Standards and Technology sõnul ei ole kahelt protsendilt inimkonnalt kvaliteetset sõrmejälge üldse võimalik võtta [101].

Liu et al [102] on uurinud kasutaja pidevtuvastamist käekuju ja -joonte kaudu juhtseadmele paigutatud sensorite abil. Nemad keskendusid juhtkangidele (*operating rod*), nagu on lennukil, mootorrattal või ekskavaatoril, aga tegelikult saab sama tehnoloogia üle kanda ka arvutihiirtele.

Midagi analoogset on teinud Fujitsu oma PalmSecure [103] tehnoloogiat toetava hiirega [104]. Peopesas asuvate veenide järgi autentimist peetakse hetkel kõige turvalisemaks biomeetriliseks tuvastusmeetodiks, sest veenide asetus on igal inimesel unikaalne, ei muutu elu jooksul ning ei sõltu välisteguritest, nagu temperatuur või niiskus. Infrapunase valguse abil veenivere hapnikusisalduse jälgimine raskendab suuresti antud biomeetrilise näitaja võltsimist. Kahjuks on käesoleval hetkel Fujitsu PalmSecure tehnoloogia puutevaba, mis tähendab, et kuigi veenimustri lugeja on spetsiaalse arvutihiire sisse integreeritud, on kasutaja tuvastamiseks tarvilik peopesa hiirelt tõsta ja kätt seadme kohal hoida, mistõttu ei ole tegemist täielikult passiivse ja pideva autentimismeetodiga.

Eelpool mainitud lahendused eeldavad spetsiaalse riistvaraga hiire olemasolu, mida ei saa sisseastumiseksami sooritajalt nõuda, mistõttu ei ole need antud kontekstis rakendatavad.

### Kergbiomeetria

Kergbiomeetriaks (*soft biometrics*) nimetatakse inimkeha eristatavatel välistunnustel (sugu, vanus, kasv, kaal, rass, nahavärv, silmavärv, juustevärv, armid, sünnimärgid, tätoveeringud) põhinevat liigituslikku, kuid enamasti mitte individualiseerivat biomeetriat [105]. Kuigi need tunnused pole unikaalsed ja neid on võimalik muuta ning võltsida (meik, kontsad, mask, parukas), annavad nad siiski kasutajast mõningase ülevaate, mistõttu saab neid kasutada koos teiste autentimissüsteemidega [106]. Kergbiomeetrilisi tunnuseid ei hoita andmebaasis, vaid need salvestatakse käesoleva sessiooni võrdluse tarbeks sisselogimise hetkel [107].

RangeForce puhul tasuks kaaluda näiteks soo, rassi, naha- ja juustevärvi ning näopiirkonnas olevate armide, sünnimärkide ja tätoveeringude jälgimist, kuna nende kohta on võimalik infot koguda veebikaamera vahendusel ja need kergbiomeetria tunnused toetaksid isiku kontrollimist videopildi ja näotuvastuse baasil.

### Muu

Kasutajat saab pidevtuvastada ka näiteks ajutegevuse alusel, jälgides pea külge kinnitatud anduritega ajusignaale või muutusi hemoglobiinis (veres) näiteks spektroskoopia või elektroentsefalograafia (EEG) abil [5]. Ajutegevus sõltub keskkonnast, ajutisest ja füüsilisest seisundist, kuid võrreldes ajutegevust puhkehetkel ja ülesande lahendamise (trükkimise) ajal võib inimeste lõikes näha mõningaid erinevusi, mille alusel kasutajaid tuvastada, kusjuures paremini ilmnevad need just puhkehetkel. Mida rohkem sensoreid, seda parem tulemus. Ajuaktiivsust jälgides on võimalik kontrollida, kas sensoreid kandev kandidaat tegeleb parasjagu sisseastumiseksami lahendamise või millegi muuga.

Ka elektrokardiogrammiga (EKG) südametegevust mõõtes on võimalik kasutajat autentida [3]. Küll aga võib südametegevuse abil kasutaja tuvastamine olla ajamahukam protsess, sest kui näiteks näopildi puhul on analüüsimiseks võimalik saada 30 kaadrit sekundis, siis süda lööb keskmiselt 1-1.5 korda sekundis, mistõttu kulub süsteemi treenimiseks kauem aega. Probleemiks võib osutuda ka füsioloogiliste ja psühholoogiliste muutuste, nagu kehaline aktiivsus, toitumine, haigused, hingamine või elektroodide asetus, mõju EKG signaalidele, mida tuleb sobivat robustset autentimissüsteemi disainides arvesse võtta. Ühe potentsiaalse dünaamiliselt kogutud andmete põhjal usalduskvoote muutva lahenduse, mis töötab ka väheste müra sisaldavate andmete peal ja paremini kui varasemad lahendused (EER = 7.89%), on välja pakkunud Louis et al [3]. Südemetegevuse mõõtmist autorooli integreeritud elektroodidega on kasutatud ka autojuhtide fookuse ja väsimustaseme kontrollimiseks ning nende pidevaks isikutuvastuseks [108].

Iga inimkeha reageerib erinevalt, kui seda mõjutada madalpinge impulsiga, sest elektrijuhtivus ja signaali nõrgenemise intensiivsus sõltub luustruktuurist, lihaste tihedusest, rasvasisaldusest ja veresoonte asendist ning suurusest [66]. Seetõttu saab kasutajat tuvastada, kui suunata ühte peopessa madalpinge elektriimpulss ja ülekande tulemust teisest peopesast mõõta. Kui teiste autentimismeetodite (näotuvastus, sõrmejälg) korral on süsteemide petmine taasesituse meetodil lihtne, siis keha reaktsiooni elektrilisele impulsile on äärmiselt raske replikeerida, kuna taasesitamiseks on vaja täpselt sama juhtivusega riistvara, mistõttu on tegemist ühe turvalisema tuvastusmeetodiga. Elektrit juhtivast materjalist või elektrit juhtiva kihiga kaetud klaviatuuri (ja hiire) olemasolul saab trükkimise ajal sõrmeotstel edastatud ja mõõdetud elektriimpulsse kasutada kasutaja pidevtuvastamise eesmärgil.

Ka nutikellade ja aktiivsusmonitoride sensoritest kogutud info (sammude arv, südamerütm/pulss, kalorikulu) abil on võimalik kasutajat tuvastada [109], kuigi antud meetodi puhul on kasutaja edukaks tuvastamiseks vaja laialdast võrdlusandmestikku kasutaja tegevuse ja kehalise aktiivsuse kohta. Küll aga saaks aktiivsusmonitore kasutada, kontrollimaks kasutaja reaktsiooni erinevatele stiimulitele, näiteks südamerütmi löögisageduse suurenemine äkilise ehmatava foto või videoklipi kuvamisel ekraanile.

Kõik antud peatükis mainitud tuvastusmeetodid on kasutaja jaoks passiivsed, see tähendab, et kasutaja tööjärge ei segata, vaid autentimine toimub taustal. Küll aga nõuavad käsitletud tuvastusmeetodid eririistvara või lisaseadmete olemasolu, mida ei saa kandidaatidelt nõuda, mistõttu ei ole ükski käsitletud meetod TTÜ küberkaitse sisseastumiseksami jaoks sobilik.

## Silmade liikumise ja fookuspunkti jälgimine

Silmade liikumine kuulub käitumusliku biomeetria alla. Silmaliikumisdünaamika puhul jälgitakse pilgu liikumist ekraanil. Sageli on selle professionaalselt tegemiseks vaja eririistvara, nagu peatugi [110], infrapunafiltriga kaamera ja infrapunase valguse allikas, et suurendada pupilli avastamise ja jälgimise täpsust, aga mõne lihtsama lahenduse puhul piisab ka sisseehitatud veebikaamerast. Silmade liikumise analüüs on ideaalne multibiomeetriliste süsteemide jaoks, eraldiseisvalt mitte nii väga [110]. Silmade liikumine sõltub nii nende füüsilisest ehitusest kui ka neuroloogilistest faktoritest [111], mistõttu on masina abil silma tegevuse imiteerimine keeruline [110]. Silmade liikumise dünaamika jälgimist kasutatakse muuhulgas kasutajaliideste ja reklaamide analüüsimiseks, silmahaiguste diagnoosimiseks [112] või sisendseadme asemel nende erivajadustega inimeste puhul, kes ei saa arvutit tavapärasel moel hiire ja klaviatuuri abil kasutada [113].

Probleemiks on peaasendi muutumine jälgimisprotsessi ajal [114], [115]. Kasutaja silmade või pea külge kinnitatavad süsteemid töötavad paremini kui arvuti küljes oleva kaameraga süsteem, mis ei võta arvesse kasutaja pea liikumist ekraani suhtes ja töötab hästi vaid seni, kuni peaasend on sama, mis kalibreerimise ajal. Üheks võimalikuks lahenduseks oleks kaasata näotuvastust ning näoasendi ja silmade positsiooni abil näos pilgu liikumise jälgimist parendada. Analoogse lahenduse näotuvastuseks ja pilgu jälgimiseks treenitud närvivõrguga on välja pakkunud Bäck [116] ja Cheung et Peng [112]. Bäck võttis pea asendit arvesse silmaiirise, välisnurga ja ninasõõrmete abil. Antud tunnusjooned valiti, kuna neid on ülejäänud näost lihtne avastada ja need ei sõltu kasutaja emotsioonidest. Bäcki süsteem ei tööta küll sama hästi, kui tol hetkel turul olevad, aga pakub siiski alternatiivi infrapunast kasutavatele lahendustele. Cheung et Peng-i arvutile ja veebikaamerale suunatud meetodiga eraldati samuti näokujutisest silmaala, millest omakorda tuvastati iirise keskme ja silma sisenurga (silmatorkavam ja vähem tundlik näoilme muutumisele kui välisnurk) asukoht, mille alusel pilgu suunda arvutada. Erinevate valgustingimuste (päevavalgus, LED-, luminofoorlamp) ühtlustamiseks/kompenseerimiseks ja näopiirkonna eraldamise hõlbustamiseks kasutati heledustasemete reguleerimist histogrammide abil. Pea asendi kalkuleerimiseks jälgiti mitmeid punkte põskedel, kulmudel, silmadel, ninal ja suul. Cheung et Peng-i välja pakutud lahendus suudab pilku jälgida ilma eelneva treenimiseta. Vähese peaasendi muutuse (kuni 15 kraadi) ja staatilise näoilme korral saavutati ligikaudu 2.27 kraadine täpsus.

Silmade kaadrist väljumist ja peaasendi muutumise mõju erinevatele olemasolevatele pilgujälgimislahendustele on uurinud näiteks [115], kes tõestasid, et antud valdkonnas on veel arenguruumi. Infrapunalahendusi kasutades võib takistavaks faktoriks osutuda ka prillide kandmine, sest klaasid võivad peegeldada arvutiekraanilt tulevat valgust ja takistada seega silma tuvastamist. Tavavalgust kasutades pole prillide kasutamine niivõrd suureks takistuseks [112]. Kindlasti nõuavad pilgujälgimisrakendused eelnevat kalibreerimist, et kasutaja pilgu suunda korrektselt jälgida.

Silmade fookust autentimise eesmärgil kasutamiseks on uuritud näotuvastust ja pilku ühendava SAFE autentimissüsteemi raames [117], kus kasutaja peab registreerimisel valima salajaste ikoonide kogu, millest suvaliselt valituna ühte hilisema autentimisprotsessi käigus sarnaste peibutusikoonide seast tuvastama ja silmadega jälgima peab. SAFE lahendus kasutab seadme (arvuti, telefon) esikaamerat, kaht infrapunavalguse allikat ja üht infrapunafiltriga kaamerat, mille abil tuvastatakse kasutaja pupillide asend ja liikumine.

Sirur et Pendse on välja pakkunud hääle, silmade ja pilgutamise kombinatsiooniga arvuti kontrollimise lahenduse [118], kus kasutaja kannab spetsiaalset kiivrit, mille külge on kinnitatud kaks kaamerat, filtrid ja infrapunase valguse allikas. Kuna silmaiiris ja pupill neelavad infrapunast valgust erinevalt, on võimalik paika panna pupilli asukoht ja vaate suund. Kaameratest saadava info põhjal arvutatakse välja kasutaja silmade vaatenurk ekraani suhtes ja kasutajale omased iirist kirjeldavad atribuudid, mille alusel on võimalik isikut tuvastada. Sirur et Pendse lahendus erineb eelnevatest selle poolest, et võtab enam arvesse ka asiaatide silmade ehitust ja silmamuna osaliselt katvat silmalaugu.

Eririistvarata on pilgujälgimist uurinud Sewell ja Komogortsev [119], kes kasutasid oma töös sülearvuti sisseehitatud kaamerat, koolile või kontorile sarnanevaid valgustingimusi ja närvivõrku, mis treeniti pupilli liikumist jälgima.

Silmade liikumise dünaamika sõltub täidetavast ülesandest. Sotsiaalmeedia veebilehte uurides liiguvad silmad teistmoodi kui RangeForce süsteemis küberkaitse sisseastumiseksamit lahendades. Seetõttu on see hea meetod kindlustamaks, et kaamera ees olev isik tegeleb aktiivselt eksami lahendamisega, mitte ei lase variisikul eksamit enda eest sooritada, olles ise sotsiaalmeedias, kaamera näotuvastuse abil autentimise tingimuse täitmiseks enda poole suunatud.

Antud kaitsemeedet oleks võimalik üle kavaldada, kasutades eksami lahendamiseks kaht ekraani, kus mõlemal kuvatakse sama pilt RangeForce testist, kusjuures kaamera on suunatud tegeliku kandidaadi, mitte variisiku, poole. Nii vastab tegeliku kandidaadi silmade liikumine testimiskeskkonna kasutamisel eeldatavale. Et sellist situatsiooni välistada, tuleb arvesse võtta, et silmade liikumine on korrelatsioonis hiire liikumisega. Kuna enamasti fikseeritakse esmalt silmadega arvutiekraanil fookuspunkt, kuhu seejärel hiirega liigutakse, mitte vastupidi, siis võib eeldada, et ilma valjusti oma kavatsustest tegelikule kandidaadile teada andmata ei saa variisik hiirt soovitud kohta liigutada nii, et tegeliku kandidaadi silmad keskenduksid kursori asemel ekraaniobjektile, millel lõpuks peatutakse. Omavahelist suulist ja kirjalikku kommunikatsiooni saab takistada ruumi heli analüüsides, märkides ohukohtadena inimkõne kostumise või trükkimisheli esinemise ajal, kui RangeForce süsteemis tekstisisestust ei toimu.

## Välise lisaekraani keelamine

Mõned võimalikud ründestsenaariumid kasutavad ära võimalust duplitseerida pilti mitmel monitoril. Näiteks võib silmade liikumist ja näotuvastust kasutavat kaitsesüsteemi petta, kui arvutis sooritab eksamit variisik, kuid näotuvastust teostav ja silmade liikumist analüüsiv kaamera on suunatud tegeliku kandidaadi suunas, kes jälgib variisiku eksamisooritust lisaekraanilt. Nii liiguvad kandidaadi silmad RangeForce süsteemiga kooskõlas ning keerulisem on tuvastada, et tegelikult kandidaat vaid jälgib ekraanil toimuvat. Sellest tulenevalt on oluline tuvastada lisaekraani olemasolu ning paluda kasutajal see eemaldada. Näiteks Windowsi operatsioonisüsteemi puhul on selleks võimalik kasutada funktsiooni EnumDisplayMonitors [120] või EnumDisplayDevices [121] ja Linuxil tööriista xrandr [122].

## Väliste rakenduste keelamine

Selleks, et eksaminand ei saaks testi sooritamise ajal suhtlusprogrammide kaudu abilistega konsulteerida, tuleks keelata välised rakendused nii kasutaja arvutis kui ka RangeForce virtuaalmasinas. Üks võimalus selleks oleks kasutada olemasolevaid ekraanilukustusprogramme, mis takistavad rakenduste vahelist navigeerimist testi tegemise ajal. Alternatiivselt võib disainida spetsiaalselt RangeForce sisseastumiseksami tarbeks koostatud turvalise veebilehitseja, milles on võimalik avada vaid sisseastumiseksami keskkond ja mis teavitab ülikooli, kui veebilehitseja aken pole aktiivne ehk on alust arvata, et kasutajal on tol hetkel lahti mõni teine programm. Turvalisest veebilehitsejast väljumise takistamiseks võib keelata hiire paremkliki, funktsiooniklahvid või muud akende vahel liikumist võimaldavad klahvikombinatsioonid (Ctrl+Alt+Del, Alt+Tab). Turul on mitmeid analoogseid kommertslahendusi, näiteks Respondus [123] või Safe Exam Browser [124], kuid kaaluda võib ka spetsiaalset CD-lt käivituvat lukustussüsteemi [38]

Alternatiivne variant on tarkvaraliselt teiste programmide avamine lubada, kuid pidada arvestust aktiivsete akende üle ja kui neid tuvastatakse lubatud limiidist rohkem, kuvada hoiatus, mis palub aken sulgeda, ning salvestada kuvapilt kasutaja ekraanist hilisemaks ülevaatamiseks. Küsides infot aktiivsete akende kohta operatsioonisüsteemi API-lt, on avastustäpsus 100% [33].

Kuna RangeForce test toimub virtuaalmasinas, tuleb otsustada, milliseid rakendusi ja veebilehti ning millisel määral blokeerida lokaalses masinas ja milliseid virtuaalmasinas, kui üldse. Koostöös RangeForce keskkonna arendajatega oleks mõeldav süsteemisiseselt sisseastumiseksami tarbeks ainult teatud rakenduste ja veebilehtede lubamine. Eksaminandidel on lubatud kasutada otsingumootoreid (Google, Bing), kuid keelatud vahetada infot suhtlusprogrammide (Facebook, VK) vahendusel. Seega peaks vähemalt ühes skoobis olema lubatud veebilehitseja kasutamine, aga piirangutega, nii et keelatud leheküljed oleksid blokeeritud. Tõenäoliselt oleks kõige lihtsam keelata kõik rakendused lokaalses masinas ja lubada osaliselt virtuaalmasinas, kus kontrollimine ja tuvastus on lihtsam. RangeForce virtuaalmasinas oleva veebilehitseja saab juba eelnevalt seadistada nii, et eksami läbiviija poolt loetletud veebilehekülgedele ligipääs puudub. Samas on võimalik hiljem logifailidest saada infot testi jooksul avatud rakendustest ja sooritatud tegevustest, mispuhul ei oleks tarvilik ühtegi rakendust blokeerida, eeldusel, et kandidaati on enne testi tegemist keelatud rakendustest teavitatud. Igatahes vähendab kontrolli viimine RangeForce keskkonna poolele ohtu, et eksaminand saab kaitsetarkvara saboteerida, näiteks selle lähtekoodi modifitseerides.

Lukustusbrauserit saaks petta, kui lokaalses masinas jooksutada virtuaalmasinat, milles omakorda käivitada lukustusbrauser, milles avaneb RangeForce test. Nii oleksid rakendused blokeeritud vaid kasutaja lokaalses masinas jooksvas virtuaalmasinas, mitte lokaalses masinas endas, võimaldades lokaalses masinas blokeeringust hoolimata kõrvalisi programme kasutada. Et selline olukord välistada, on vaja tuvastada, kas lukustusbrauser töötab virtuaalkeskkonnas või mitte. Selleks võib näiteks kontrollida/uurida hüperviisori olemasolu CPUID-d järgi [125], registrivõtmeid, mälu, virtuaalmasina ja hosti vahelist suhtluskanalit, protsesse ja faile, MAC-aadressi, BIOS-i seerianumbrit [126], väljuvate IP-pakettide TCP-päiste kontroll-lippe, eluiga, ID-sid [127] ja ajatempleid [128]. RangeForce testi lahendamiseks mõeldud lukustusbrauser ei tohi käivituda virtuaalmasinas. Selle asemel tuleb kasutajat tekkinud olukorrast teavitada, paluda virtuaalmasinat mitte kasutada ning brauser sulgeda.

Sellised ennetusmeetmed välistaksid ekraanijagamis- ja suhtlusprogrammide kasutamise nii lokaalses kui ka virtuaalmasinas. Alternatiiviks väliste rakenduste keelamisele võiks olla ka pidev või perioodiline kuvapildi jälgimine, tuvastamaks keelatud rakendusi, kuid lukustusbrauseri kasutamisel muutub kuvapildi eraldi jälgimine tarbetuks, mistõttu ei ole seda kaitsemeedet antud töös lähemalt käsiteldud.

Kui testitegemise keskkond on isoleeritud, tuleb aga kaaluda varianti, et eksaminand kasutab info edastamiseks ja juhiste saamiseks lisaseadmeid, nagu ruumis viibiv kõrvaline isik, teine arvuti või nutitelefon, mistõttu on oluline jälgida ruumi heli ja videopilti.

## Ruumi helianalüüs

Kui arvutipõhine suhtlus erinevate ekraanijagamise ja suhtlusprogrammide abil on keelatud, tuleks kontrollida ka seda, et infoedastus ei toimuks suuliselt või muude lisaseadmetega. Selleks oleks praktiline kuulata ruumi taustaheli ning tuvastada sealt inimkõne. Kuna sisseastumiseksami puhul on võimalik nõuda täielikku vaikust, välistades ka kandidaadi valjuhäälse arutelu, viitab taustal esinev kõne kõrvaliste isikute viibimisele ruumis.

Kõnetuvastust võivad häirida muud ruumis esinevad helid, nagu tooli liikumine, klahvivajutuste heli, hingamine, köhimine. Selleks, et iga vähimgi heli kõnetuvastussüsteemi ei käivitaks, võib analüüsida heli valjudust, sagedust või kestust ja süsteemi eelnevalt positiivsete (kõne, sosistamine) ja negatiivsete (hingamine, köhimine, konditsioneer, linnaliiklus) näidistega treenida [33]. Et välistada taustaheli analüüsimise saboteerimist mikrofoni blokeerimise või muu analoogse meetodi näol, võib ebaregulaarse perioodi järel kõlaritest kostuda lasta signaalil. Kui mikrofon helisignaali kinni ei püüa, on kandidaat helianalüüsile vahele seganud.

Samuti võib taustaheli analüüsimine aimu anda teise arvuti abil toimuvast kommunikatsioonist. Kui sisseastumiseksami kaitsesüsteem analüüsib klahvivajutusi, saab trükkimisheli esinemisel, aga klahvivajutuste puudumisel järeldada, et ruumis on ka teine klaviatuuriga seade, mille kaudu on võimalik infot edastada ja seega eksamikorda rikkuda.

## Ruumi pildianalüüs

Selleks, et takistada väljaspool kaamera vaatevälja olevate abivahendite kasutamist või kõrvaliste isikute viibimist ruumis, tuleks kandidaadil enne eksami algust lindistada 360-kraadine video ruumist, kus eksamit sooritatakse, kasutades selleks veebikaamerat. Oleks hea, kui tolleks hetkeks oleks võimalik luua ühendus inimesest järelevaatajaga, kes veenduks keskkonna sobilikkuses ja vajadusel paluks sobimatud esemed eemaldada, kuid kui see pole võimalik, tuleb eksaminandile koostada selge ja arusaadav juhend korrektse eksamikeskkonna ning lubatud materjalide ja seadmete kohta ruumis ning ruumist 360-kraadise ülevaate andev videoklipp hiljem eksami läbiviijal manuaalselt üle vaadata.

Ruumi tuleks veebikaamera videopildi vahendusel analüüsida ka hiljem, eksami sooritamise ajal, veendumaks, et protsessi käigus ei lisandu ruumi inimesi. Selleks võib kasutada näotuvastust, jälgides lisaks esiplaanil oleva eksaminandi näole taustale tekkivaid näokujutisi, või liikumisanalüüsi, märgistades ohukohtadena kaadris toimuva lisaliikumise. Liikumise analüüs peaks olema võimalikult robustne ja pigem vähetundlik, kuna vastasel juhul võib see iga eksaminandi toolis tahapoole nõjatumise märgistada kui taustaliikumise. Üks võimalus oleks siinkohal eeldada, et eksaminandi keha asub vahetult tema näo all [80], [107] ning analüüsida liikumist piirkonnas, mis ei ole märgistatud kui pea või keha ning loetakse seetõttu taustaks. Antud juhul võib süsteemi vallandada kasutaja ringutamine.

Kõrgtasemelise süsteemi puhul võiks kaaluda erinevate esemete, näiteks telefon, lisaarvuti, teksti sisaldavad plakatid, raamatud ja lehed, tuvastamist videopildist [33], kuid usutavasti ei ole see RangeForce sisseastumiseksami algversiooni jaoks äärmiselt vajalik lisafunktsioon ja võib pigem süsteemi muuta asjatult tundlikuks.

Proovitud peatükis X.

## Muu

Jälgides IP-aadresse, millelt sisseastumiseksamit lahendatakse, on võimalik välistada eksami lahendamise teenus [129]. Nimelt, kui sisseastumiseksamit lahendab ühelt ja samalt IP-aadressilt mitu erinevat kandidaati, võib tegemist olla juhtumiga, kus pakutakse teenust eksami sooritamiseks. Teisalt ei ole võimalik konkreetset IP-aadressi blokeerida, kuna tegemist võib olla ka situatsiooniga, kus kandidaadid lahendavad testi ühes ja samas avalikus internetipunktis, nagu näiteks raamatukogu, ülikool või ühiselamu. Korduvate IP-aadresside puhul on võimalik kandidaadid märgistada ja testimistingimusi vestlusvoorus täpsustada.

Võimalik on analüüsida ka testi sooritamiseks kulunud aega. Kui see on liiga lühike, võis ülesanne olla varasemalt teada või läbi lahendatud. Liiga pikk aeg võib aga ka vihjata sellele, et testi lahendamist pikendas kellegi teisega konsulteerimine.

Huvitav kaitsemeede oleks kasutada „meepoti“ (*honey pot*) meetodit ehk koostada testi vastuseid või juhiseid sisaldav veebilehekülg, millele navigeerides tuvastatakse kasutaja võõrküpsiste (*third party cookie*) või IP-aadressi kaasabil, eeldusel, et meepoti-lehekülg avatakse samas seadmes, kus sooritatakse testi [21]. Loomulikult ei sisaldaks antud lehekülg tegelikult ühtegi vastust, kuid ülesande teksti muutmata kujul otsides kuvataks meepoti-lehekülg esimesena. Sellisel juhul on võimalik eristada kandidaate, kes üritavad leida ülesande samm-sammulist lahenduskäiku, nendest, kes kasutavad otsingut alamülesande probleemi lahendamiseks.

# Tobii katse

Ühe töös välja toodud kaitsemeetme kohaselt on silmade liikumise ja fookuspunkti alusel võimalik kindlaks teha, kas kasutaja tegeleb parasjagu sisseastumistesti lahendamisega ja kas ta sooritab tegevusi ise (vt Peatükk 5.3, lk 48). Selle kinnitamiseks läbi viidud uuringut sooritati Tallinna Tehnikaülikooli Innovatsiooni- ja ettevõtluskeskuses Mektory [130], kus on võimalik kasutada Tobii Pro silmajälgimislahendusi.

Kolme eriliigilise katse abil uuriti järgnevaid teese:

* Parasjagu külastatavat veebilehte on võimalik kindlaks määrata selle alusel, kuhu kasutaja veebilehel olles kõige sagedamini vaatab.
* Tegevuste, nagu pilgu ja hiire liikumine, järjestus sõltub sellest, kas RangeForce laborit sooritatakse ise või vaadatakse, kuidas lahendab ülesannet keegi teine.
* Pilgu liikumistrajektoor teksti lugemisel erineb trajektoorist, mis tekib meediasisu (fotod, videod) vaadates.

Alljärgnevalt on esitatud uurimuse jooksul kasutusel olnud riist- ja tarkvaralahendused, sooritatud katsed, tekkinud probleemid ja tulemused.

## Töökoht

Antud uurimuses oli kasutusel infrapunase valgusega silmade liikumist jälgiv ja lindistav kaameraseade Tobii Pro X2-30 Eye Tracker [131]. Ühe sekundi jooksul 30 korda sensoritelt kasutaja silmade liikumise kohta infot küsiv seadis on kõigest 18.4 cm laiune ja sellest tulenevalt sobilik mitmeteks erinevateks uuringuteks alates reaalelulistest situatsioonidest telefoni- ja arvutiekraanidel toimuvani välja. Tobii Pro X2-30 sobib kasutajate silma fookuspunkti analüüsimiseks, kuid ei ole piisavalt väikese diskreetimistaktiga, et uurida täpsemat silma hüplemist ehk sakaade.

Jälgimisprotsessi ajal valgustab seadeldis kasutajat lähi-infrapunase valgusega, mis peegeldub tagasi silma sarvkestalt [132]. Sensoritest saadud andmete alusel arvutatakse välja silmamunade asend ja pilgu täpne asukoht ekraanil ehk silmade fookuspunkt. Kuna silmade asukoha määramiseks kasutatakse infrapunast valgust, osutub takistuseks prilliklaasidelt peegelduv kuvarivalgus, mistõttu ei saa seda kasutada prillidega. Samuti raskendab jälgimisprotsessi liigne päevavalgus, mida oli Mektory laboris hoolimata ette tõmmatud ruloodest kellaajast sõltuvalt suuremal või vähemal määral.

Tobii Pro X2-30 kasutaja ei ole kohustatud oma pead staatiliselt paigal hoidma, vaid võib seda mõningal määral liigutada ilma jälgimisprotsessi drastiliselt mõjutamata. Näiteks Tobii Pro X2-30 sensoritest 70 sentimeetri kaugusel istudes on lubatud pea liikumine 50 x 36 cm suuruses alas [133]. Samuti taastub süsteem koheselt kasutaja silmade pilgutamisest. Tobii Pro X2-30 töötamisvahemik on 40-90 cm kaugusel ekraanist.

Kleepribaga ekraani alaosa külge kinnitatud Tobii Pro X2-30 Eye Tracker oli USB-kaabli kaudu ühendatud Dell Precision T3600 tööjaamaga (vt Tabel 2). Kõikides katsetes kasutati sisendseadmetena Dell SK-3205 klaviatuuri ning esialgu Logitech’i arvutihiirt, kuid kuna uurimuse viimastel katsetel ilmnes Logitech’i hiirel kasutajate tegevust tugevasti häiriv defekt (katkine juhtmeühendus), oldi sunnitud see asendama hiirega firmalt HP.

Tabel . Eksperimendis kasutatud tööjaama tehnilised andmed.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Tööjaam | Protsessor | Taktsagedus | Muutmälu (RAM) | Operatsioonisüsteem |
| Dell Precision T3600 | Intel® Xeon® CPU E5-1650 | 3.20GHz | 16,0 GB | Windows 8 Pro,  x64 (64-bitine) |
|  |  |  |  |  |

Kasutaja näoilmet jälgiti kuvari ülaserva kinnitatud Acme CA04 USB-ühendusega välise veebikaameraga. Katsetes oli kasutusel 21.5-tolline LED-ekraan Dell U2212HM resolutsiooniga 1920x1080. Töökoht asus vahetult papiplaadi ja rulooga kinni kaetud akna all nii, et osalejad olid näoga akna poole suunatud (vt Joonis 13). Ruumi valgustasid luminofoorlambid ja läbi ruloo kumav päevavalgus.

A person sitting at a desk with a computer

Description generated with very high confidence

Joonis . Töökoht. Ekraani alaserva külge on kinnitatud kasutaja silmi jälgiv Tobii Pro X2-30 Eye Tracker ja ülaserva kasutajat ennast filmiv Acme CA04 kaamera.

Katsete koostamiseks, Tobii Pro X2-30 Eye Tracker’ist saadava info kogumiseks, visualiseerimiseks ja analüüsimiseks kasutati tarkvaralahendust Tobii Pro Studio versioon 3.2.3 (edaspidi Tobii Studio) [134]. Antud programm võimaldab stiimulina kasutada ülesannet kirjeldavaid juhendeid, küsimustikke, staatilisi pilte ja PDF-dokumente, dünaamilisi videoid, veebilehti ja kuvahõivet (*screen capture*) ning välisel seadmel (teler, teine arvuti) ja ruumis toimuvat (vt Joonis 13) [132].



Joonis . Tobii Pro Studio stiimulelementide valik testi seadistamise vaates.

Käesolevas uurimuses hõlmab testide koostamiseks kasutatud elementide kogu videoid, veebilehti ja kuvahõivet. Kuigi Tobii Studio võimaldab katset koheselt alustada eelnevalt kindlaks määratud veebilehelt, kasutades selleks testi koostamisel vastavat elementi (*web*), toetas Mektory arvutis olev versioon vaid Internet Explorer veebilehitsejat, kus RangeForce veebisait korrektselt ei avanenud, mistõttu otsustati veebielemendi asemel kuvahõive kasuks ning uurimuse all olevad veebilehed avati taustal manuaalselt enne katse algust.

## Katsete ülesehitus

Uurimus koosnes kolme liiki alamkatsetest (vt Tabel 3), mille raames üritati leida erinevusi kasutajate käitumises sisseastumistesti iseseisvalt sooritades, kellegi teise sooritust jälgides ja vähemalt ühel meediasisuga veebilehel (Postimees, YouTube) tavapäraseid toiminguid tehes. Postimehe [135] ja YouTube’i [136] veebilehed valiti kui ühed sageli kasutatavad veebisaidid. Kuna Tobii Studio salvestab kuvahõive, klaviatuuri ja hiire sisendi, otsustati osalejate privaatsuse käesolevast uurimusest välja jätta sotsiaalmeedia veebileheküljed, nagu Facebook või Instagram. Katseülesannete täitmise ajal salvestati osalejate nõusolekul nende näoilmeid, silmade liikumist, sisendseadmete kasutust ja ruumiheli.

Tabel . Katsed.

| Katse tüüp | Katses kasutatav materjal | Katse jooksul salvestatav materjal | Kirjeldus | Eesmärk |
| --- | --- | --- | --- | --- |
| Vaatamine | Eelnevalt lindistatud ekraanivideo RangeForce keskkonnas labori lahendamisest | Kasutajavideo, ruumiheli, silmade liikumine | Osaleja jälgib ligikaudu 10 minutit kestvat ekraanivideot sellest, kuidas keegi teine lahendab RangeForce keskkonnas laborit.  Keelatud on sisendseadmete (klaviatuur, hiir) kasutamine. Katse lõppeb ekraanivideo lõppedes. | Simuleerida olukorda, kus kaitsemeetmeks on näotuvastus ja silma fookuspunkti analüüs.  Võrrelda kasutaja silmade liikumist laborit ise sooritades ja kellegi teise sooritust jälgides. |
| Sooritus | RangeForce labor | Ekraanivideo, kasutajavideo, ruumiheli, silmade liikumine, hiirevajutuse asukoht,  klahvivajutuse ajahetk | Osaleja sooritab iseseisvalt RangeForce keskkonnas sissejuhatavat laborit (Apache veebiserveri konfigureerimine).  Lubatud on kasutada internetti abi otsimiseks, kuigi labori keskkonnas antavad juhised on piisavalt põhjalikud, et nende baasil labor sooritada. | Simuleerida situatsiooni, kus kasutaja ei riku eksamikorda, sooritab labori üksinda ruumis viibides iseseisvalt ja ilma keelatud abimaterjale lahendamata.  Võrrelda kasutaja silmade liikumist laborit ise sooritades ja kellegi teise sooritust jälgides. |
| Muu | Postimehe veebileht, YouTube veebileht | Ekraanivideo, kasutajavideo, ruumiheli, silmade liikumine | Kasutajal on lubatud veebilehel ilma piiranguteta ringi liikuda, alamlehti avada, artikleid ja videoid vaadata. | Võrrelda kasutaja silmade liikumist RangeForce keskkonnas ja muudel veebilehtedel. |
|  |  |  |  |  |

Katsete summaarne kestus oli ligikaudu üks astronoomiline tund, varieerudes muu valdkonna veebilehel (Postimees, YouTube) viibitud ajast ning labori sooritamise kiirusest tulenevalt. Kuna Mektory labori näol on tegemist maja päikesepoolses küljes asuva ühiskasutuses arvutiklassiga, ei olnud võimalik kõiki kaitseid sooritada samades tingimustes. Katseid sooritati mitmel eri päeval ajavahemikus alates kella üheksast hommikul kuni kella üheksani õhtul, mis tähendab, et kuigi ruumis põlesid alati luminofoorlambid ja aknad olid ruloodega blokeeritud, varieerusid valgustingimused päevavalgusest tulenevalt.

Enne iga katset teostati täpsuse suurendamiseks korduvkalibreerimine, kasutades üheksat punkti ekraanil. Kalibreerimise ajal ilmus ekraanile musta sisuga punane ring, mida kasutaja pidi pilguga jälgima, kui see läbis ekraanil ringi liikudes kõik üheksa kalibreerimispunkti (vt Joonis 14).

A group of people flying kites in the sky

Description generated with very high confidence

Joonis . Kalibreerimispunktide asukohad.

Kui kalibreerimine oli piisavalt täpne, paluti osalejatel oodata, kuni test käivitub, vastasel juhul läbiti kalibreerimisprotsess uuesti. Video vaatamise test lõppes ilma kasutajapoolse sekkumiseta, kuid kuvahõive testide puhul lõpetas osaleja testi ise eelnevalt saadud juhistele toetudes.

Osalejad viibisid katsete sooritamise ajal ruumis üldiselt üksinda, imiteerimaks ideaalset kodust eksamikeskkonda. Erandiks oli vaid kaks vaatluskatset, kus ruumis viibis lisaks katses osalejale katset läbi viiv isik, kuid kummalgi juhul ei toimunud isikute vahel suhtlust ning katsete tulemused ei kajasta märkimisväärset erinevust üksinda ja mitmekesi ruumis viibitud katsete vahel. Võimalik, et tulemusi oleks mõjutanud see, kui mitmekesi ruumis viibides oleks isikutel lubatud omavahel rääkida või muul moel infot edastada, kuid antud töö skoopi arvesse võttes tuleb seda aspekti edasi uurida hiljem.

## Osalejad

Uurimuses osalejate valim hõlmas esialgu üheksat Tallinna Tehnikaülikooli infotehnoloogia teaduskonna tudengit vanusevahemikus 21-31 eluaastat, kuid kuna kolmel neist oli raskusi ilma prillideta arvutiekraanil oleva teksti 50 sentimeetri kauguselt nägemisega, taandus uurimuses osalev grupp kuuele inimesele (vt Tabel 4), kellest üks oli sunnitud RangeForce labori lahendamiseks ekraanil olevat teksti suurendama ning üks loobus vähese kokkupuute tõttu Linuxi käsureaga laboriülesande iseseisvast lahendamisest. Kokku osales uurimuses niisiis neli meest ja kaks naist, kõik neist europiidse rassi esindajad ja mitte ükski varasemalt RangeForce keskkonnaga kokku puutunud.

Tabel . Uurimuses osalejate info. Soo lühendite selgitus: N - naine, M - mees. Katsete teostamise järjekorra lühendite selgitus: M - muu; S - sooritus; V - vaatamine.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Osaleja kood | Sugu | Silmavärv | Nägemine | Osalus uurimuses | Katsete teostamise järjekord |
| O1 | N | roheline | prillid | täielik | MSV |
| O2 | M | roheline | korrigeerimata | täielik | MVS |
| O3 | M | sinakashall | korrigeerimata | täielik | SMV |
| O4 | M | hall | prillid | täielik | VSM |
| O5 | M | roheline | prillid | mööndustega | VMS |
| O6 | N | sinakashall | korrigeerimata | osaline | MV |
|  |  |  |  |  |  |

Osalejad läbisid katsed erinevas kombinatoorses järjekorras (vt Tabel 4). Kaks osalejat sooritasid esmalt labori iseseisvalt ja vaatasid seejärel kellegi teise sooritust, kolm osalejat jälgisid eelnevalt labori kuvahõivet ja said seejärel ülesandeks sama labor ise läbida ning üks osaleja loobus labori tegemisest. Muu kategooria ülesanne teostati kas enne või pärast RangeForce’i omi või nende vahepeal. Järjekorra varieerumise põhjuseks oli uurida, kas tulemused sõltuvad sellest, kas osaleja on ülesandega eelnevalt kokku puutunud.

## Probleemid

Uurimuse teostamise faasis ilmnes nii mõnigi takistav faktor. Näiteks ei oldud esialgu arvestatud sellega, et kõigi uuringus osalejate nägemine ei võimalda neil ilma korrigeerivate vahenditeta Tobii Eye Tracker’i kasutamiseks vajalikult kauguselt ekraanil olevat teksti näha. Prille ei saanud kasutada, kuna need takistasid infrapunase valguse abil pupillide asukoha määramist. Kuigi lõplikus valimis esines ka isikuid, kes olid vajadusel valmis katse sooritamiseks läätsi kasutama, ei olnud see tarvilik, kuna nad nägid ekraanil olevat teksti piisavalt selgelt ka ilma nendeta. Üks uuringus osaleja oli sellegipoolest sunnitud RangeForce labori sooritamiseks kuvapilti suurendama ning isegi pärast seda liikus ta peaga Tobii Eye Tracker’i sensoritele ohtlikult lähedale, väljudes äärepealt jälgimisvahemikust.

Osalejad tõid esile, et võõra riistvaraga oli ülesande lahendamine ebamugavam, kui see oleks olnud harjumuspärast arvutit kasutades. Üks osaleja oli igapäevaselt harjunud kasutama ingliskeelset klaviatuuri ning oli seetõttu sunnitud poole soorituse pealt klaviatuuri keelt vahetama, häirides tema loomulikku töö kulgu.

Poole uuringu peal ilmnes, et kasutatud Logitech’i arvutihiire juhe oli katkine, mistõttu ühendus hiire ja arvuti vahel katkes sageli ning häiris uuringus osalejate toiminguid. Seetõttu otsustati katseid vigase hiirega mitte jätkata ning edaspidi kasutasid osalejad HP hiirt.

Lisaks kurtis üks katsetes osaleja ka toolide ebamugavuse tõttu. Kuigi osalejatel oli lubatud testide vahel vabalt ringi liikuda ja sirutada, loobusid paljud sellest võimalusest. Kahjuks ei olnud võimalik ka töökohal olevat tooli vahetada, kuna laboris olidki ainult üht tüüpi plastmasstoolid.

Kärsitus?

## Tulemused

Kuna katses osalejaid oli lõplikult kokku kuus, on valim liiga väike, et selle alusel laiemaid üldistusi teha, ning põhjalikumaks otsustamiseks tuleks katset korrata enamate inimestega. Küll aga on võimalik ka kuueliikmelise grupi pealt juba mõningaid järeldusi teha. Alljärgnevalt ongi välja toodud katsete tulemused ja nende põhjal tehtud soovitused.

### Soojuskaardid

Veebilehe ülesehitusest tulenevalt võib eeldada, et mõni osa leheküljest saab kasutajalt rohkem tähelepanu kui teine. See oletus saab kinnituse, kui vaadata Postimehe ja YouTube veebilehe ning RangeForce labori soojuskaarte (*heatmap*) (vt Joonis 15, Joonis 16, Joonis 17), mis annavad visualiseeritud ülevaate sellest, kui sageli kasutaja pilk teatud piirkonnas peatus [132]. Kuumkohad ehk arvuliselt kõige sagedamini tähelepanu pälvinud alad on antud töö soojuskaartidel märgitud punasena ning harvem vaadatud piirkonnad rohelisena. Soojuskaartide visualiseerimise aluseks olev ajavahemik varieerus poolest minutist viie minutini, sõltuvalt veebilehe sisu dünaamilisusest, vaataja käitumisest ning kerimistempost. Kiirelt muutuva sisu puhul (Postimees, YouTube) koostati soojuskaart lühema ajavahemiku kohta kui RangeForce labori korral, kus sisu paigutus muutus vähe.

Postimehe veebivaates on sisu vertikaalselt joondatud lehe keskossa ning ääred on tühjad või sisaldavad reklaami (vt Joonis 15). Sellest tulenevalt on ka kasutaja pilk suunatud enamasti lehe keskossa, moodustades seal ühtlase pilgupunktide klastri.

Ühtegi ülejäänutest intensiivselt eristuvat kuumkohta Postimehe soojuskaartidel ei esine.

A screenshot of a video game

Description generated with high confidence A screenshot of a cell phone

Description generated with very high confidence(a) (b)

A screenshot of a cell phone

Description generated with very high confidence A screenshot of a computer

Description generated with very high confidence

(c) (d)

Joonis . Postimehe veebilehe soojuskaardid: (a), (b) artikli lugemine; (c), (d) pealehe sirvimine.

YouTube’i veebilehe puhul sõltub soojuskaart suuresti sellest, kas videoid vaadati täisekraanvaates või minimeeritult (vt Joonis 16). Viimast on võimalik soojuskaardi põhjal kindlaks määrata, kui pilk on koondunud pigem ühte piirkonda. Täisekraanvaate puhul ühtlast joont ei eristu - soojuskaart sõltub vaadatud videost ja selles olnud pilkupüüdvatest objektidest.

A picture containing outdoor, building, object, green

Description generated with high confidence A picture containing person, building

Description generated with very high confidenceA screenshot of a computer

Description generated with very high confidence A picture containing indoor

Description generated with very high confidence

Joonis . YouTube soojuskaardid.

RangeForce labori veebileht hõivab kogu veebilehitseja akna, ulatudes nii horisontaalselt kui vertikaalselt servast servani. Labori soojuskaardid erinevad suuresti katses osalejate lõikes (vt Joonis 17). Eristuvad mõningad kuumkohad, nagu järgmise sammuni viiv nupp virtuaalmasina ülemises paremas servas, terminalisakk tegumiribal, tekstijuhiseid sisaldav ala, labori etappe näitav loetelu ja terminaliaken, kuid need sõltuvad sellest, kuidas on kasutaja paigutanud rakenduste aknad. Kuigi akende paigutusele piiranguid seatud polnud ning neid võis korduvalt ümber tõsta, oli enamikul katses osalejatest ülesande edenemist ja juhiseid sisaldav aken täisvaates üle kogu ekraani ulatuses, välja arvatud üks osaleja, kes muutis poole katse pealt juhisakna asukohta. Terminaliaknaid seevastu liigutati sageli, kuna täisekraanil juhiseid kuvades kippus too ülesande kirjeldust osaliselt katma.

A screenshot of a computer

Description generated with very high confidence A screenshot of a computer screen

Description generated with very high confidenceA screenshot of a computer screen

Description generated with very high confidence A screenshot of a computer screen

Description generated with very high confidence

Joonis . RangeForce labori akende erinevad paigutused ja vastavad soojuskaardid.

Eelnevast võib järeldada, et kasutaja pilgu soojuskaart ei ole piisav, et selle alusel üheselt määrata, millist keskkonda parasjagu kasutatakse. Kuigi võimalik on eristada veebilehti, mille sisu on koondunud ekraani keskele, nendest, mis katavad ekraani kogu ulatuses, sõltub RangeForce keskkonna soojuskaart sellest, kuidas liigutab kandidaat virtuaalmasina programmiaknaid. Seda, kas kaamera ees viibiv isik jälgib parasjagu RangeForce keskkonda, saab kontrollida labori staatiliste objektide, nagu nupud, menüüd, tegumiriba sakid, baasil. Kui kasutaja pilk peatub mainitud elementidel harva või üldse mitte, on alust arvata, et ekraanil kuvatakse parasjagu mõnd muud keskkonda ja toimumas on kehastusrünnak, kus näotuvastust teostav kaamera on suunatud ühe isiku poole, aga ülesannet lahendab vaateväljast eemal asuv abiline.

Olukorras, kus ekraanid on dubleeritud, ehk tegelik kandidaat jälgib variisiku tegevusi lisaekraani vahendusel, ei ole soojuskaardid eristatavad (vt Joonis 18). Kuna lehel kuvatavad elemendid on samad, on varieeruvus nende vaatamise sageduse vahel minimaalne, mis tähendab, et selle alusel ei ole võimalik eristada, kas kaamera ees olev isik tegeleb testi lahendamisega ise või jälgib, kuidas seda teeb keegi teine.

A screenshot of a computer screen

Description generated with very high confidence A screenshot of a computer screen

Description generated with very high confidence(a) (b)A screenshot of a computer screen

Description generated with very high confidence A screenshot of a computer

Description generated with very high confidence(c) (d)

Joonis . Vaatlejate ja sooritaja viie minuti fookuspunktide baasil koostatud soojuskaartide võrdlus: (a), (b), (c) vaatlejate soojuskaardid; (d) sooritaja soojuskaart.

Tulemustest võib järeldada, et RangeForce süsteemis lahendatava sisseastumistesti puhul on pilgu peatuspunktidel pigem toetav roll veebikeskkonna kindlaks määramisel ning ainult kuumkohtade alusel ei ole võimalik teha otsuseid isiku kohta, kelle poole silmade liikumist jälgiv kaamera suunatud on.

### Pilgu ja kursori korrelatsioon

Teisena uuriti hüpoteesi, mille kohaselt kasutaja silmade liikumine ja hiire kasutamine, spetsiifilisemalt antud tegevuste järjekord, on sõltuvuses sellest, kas kasutaja sooritab toiminguid ise (edaspidi sooritaja) või jälgib näiteks lisaekraani vahendusel, kuidas seda teeb keegi teine (edaspidi vaatleja). Eelduse kohaselt on esimesel juhul tegevuste järjekord järgmine:

1. Sooritaja suunab pilgu elemendile või selle vahetusse lähedusse.
2. Sooritaja liigub kursoriga elemendile.
3. Toimub interaktsioon (näiteks hiireklikk) kasutaja ja elemendi vahel.

Selle kinnitamiseks paluti uuringus osalejatel labor lahendada iseseisvalt, üksinda ruumis viibides ilma kelleltki teiselt juhiseid saamata.

Kommunikatsiooni puudumisel ehk kui sooritaja ei edasta vaatlejale juhiseid oma tegevuste kohta, võiks olukord olla selline:

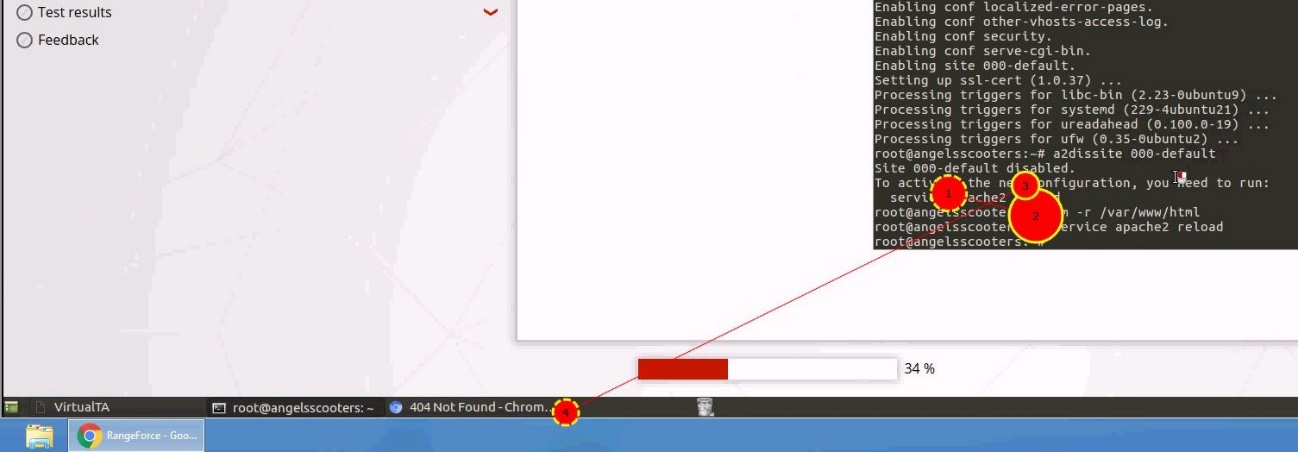
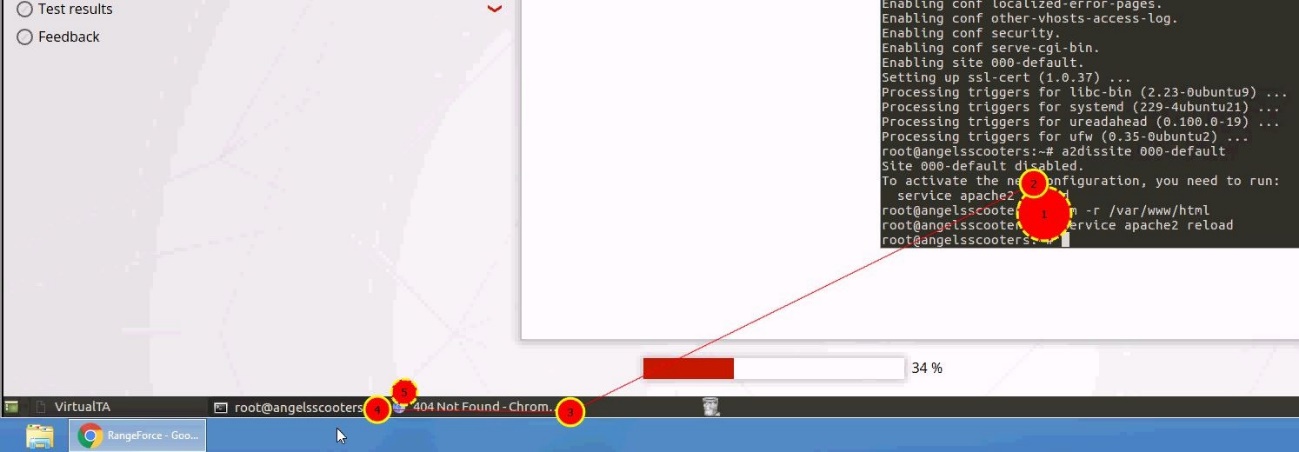
1. Kursor liigub elemendile.
2. Vaatleja jälgib pilguga liikuvat kursorit või kohta, kus kursor liikumise lõpetas.
3. Toimub interaktsioon kasutaja ja elemendi vahel.

Laboris oli ainult üks pilgujälgimisseade, mis võimaldas samal ajal jälgida ainult üht osalejat. Seetõttu ei olnud võimalik tekitada olukorda, kus laborit lahendab variisik ning pilgupunkti jälgija petmiseks kasutatakse kaht ekraani, millel on dubleeritud pilt RangeForce labori keskkonnast. Sellest tulenevalt lindistati Tobii Studio abil esmalt kuvahõive kahe osaleja sooritusest, mida näidati hiljem osalejatele kuvahõive video kujul. Taolise simulatsiooni abil oli võimalik kõrvutada sooritaja ja jälgijate silmade liikumist.

Uurimisküsimus saab kinnitust juba ainuüksi visuaalse vaatluse käigus (vt Joonis 19), kus on näha, et lõpetades tegevuse terminaliaknas, suunab labori sooritaja pilgu tegumiribal olevale veebilehitseja avamise sakile sooviga terminalis tehtud käskude tulemust kontrollida. Kui kasutaja on pilguga paika pannud saki asukoha, liigutab ta selle lähedusse hiirekursori, valmistudes pärast kursori asukoha korrigeerimist sakile vajutama. Katses kogutud arvandmete kohaselt keskendub sooritaja antud joonisel kujutatud klikitava punkti lähipiirkonda (67 pikslit) ligikaudu pool sekundit enne vajutuse toimumist.

Vaatlejad seevastu ei tea, mis tegevust sooritaja järgnevalt teha tahab ning jälgivad pilguga terminaliakent, kus toimus viimane tegevus, kuni märkavad kursori liikumisest, et fookuspunkt on muutunud. Kuna tegumiribal veebilehitseja ikooni klikkimine avab uue akna, haarab vaatlejate tähelepanu hoopis avanenud rakendus ning kuigi nende pilgud liikusid esialgu tegumiriba suunas, ei jõudnud antud juhul ühegi vaatleja pilk vajutatud nupu lähedale, vaid liikus avanenud aknasse.

Samuti ei pööranud sooritajad hiire liigutamise kiirusele teadlikult tähelepanu, millest tulenevalt muutus kursori asukoht ekraanil kohati kiirelt ja hüplikult, tehes vaatlejatele kursori jälgimise keerulisemaks. Sellisel juhul keskendusid vaatlejad tempokama liikumise korral kursorile alles siis, kui see oli peatunud.

(a)  
(b)  
A screenshot of a cell phone

Description generated with very high confidence(c)

Joonis . Korrelatsioon pilgu ja hiire liikumise vahel: (a) ajahetkel t-1 suunab labori sooritaja pilgu tegumiriba brauserisaki poole, kursor asub terminaliaknas; (b) ajahetkel t liigutab labori sooritaja kursorit saki suunas, kursor asub tegumiribal; (c) ajahetkel t liigub üks soorituse vaatajatest pilguga tegumiribal asuva kursori suunas, ülejäänud vaatavad alles terminaliakent.

Juhuslike hiirevajutuste puhul, näiteks kogemata hiireklahvile vajutades või soovides taustal olevat akent aktiveerida, ei esine äratuntavat seost vajutuse asukoha, pilgupunkti ja tegevuste järjekorra vahel.

Kuna neli osalejat ei teadnud ja kaks osalejat teadsid enne katses osalemist uurimuse tagamaid, on võimalik võrrelda, kuidas erineb käitumine jälgimise ja sooritamise puhul olukorras, kus süsteemi ei üritata petta või petetakse tahtlikult. Need, kes olid katse ülesehitusest ja eesmärgist teadlikud (edaspidi ennustajad), said ülesandeks sooritaja tegevusi ette ennustada ja vastavalt sellele oma pilku enne hiire liikumist suunata.

Kuigi ennustajad reageerisid hiire liikumisele aktiivsemalt, ei olnud kumbki neist võimeline pilguga järgmisena fookusesse sattuvat elementi jälgima enne, kui sooritaja oli elemendile keskendunud ja paljastas kursori liikumise sihi. Kui liikumissuund oli juba teada, suutsid mõlemad ennustajad väheste ekraanil olevate elementide seast kindlaks määrata selle, milleni sooritaja liigub. Ennustada oli keerulisem, kui sooritaja tegevus kaldus kõrvale tavapärasest labori kulust, näiteks avati kogemata vale aken.

### Keskkonna ja silmade liikumise seos

Seda, millega kasutaja parasjagu tegeleb, on võimalik osaliselt kindlaks määrata selle järgi, kuidas liigub tema pilk arvutiekraanil. Näiteks testilist sisu lugedes liigub pilk üldjuhul ridade kaupa vasakule paremale ja ülalt alla (vt Joonis 20).

A close up of a logo

Description generated with very high confidence

Joonis . Silmade liikumine teksti lugedes.

Suuremal hulgal graafilist sisu, nagu pildid ja videod, sisaldavas keskkonnas liigub pilk hüplikumalt (vt Joonis 21). Postimehe pealehel liiguvad silmad paremalt vasakule uudiste pealkirjade lugemise ajal, kajastudes joonisel horisontaalsete joontena, kuid reklaamid ja uudiste pealkirjade kohal juures olevad fotod hajutavad pilku ka diagonaal- ja vertikaalsihis. YouTube’i keskkonnas täisekraanil videot vaadates on pilk veelgi enam hajutatud, peatudes vaid tol ajahetkel videos olevatel pilkupüüdvatel objektidel.

A picture containing indoor, object, sitting

Description generated with high confidence A picture containing indoor

Description generated with high confidence(a) (b)

Joonis . Silmade liikumine graafilisemas keskkonnas: (a) Postimeest lugedes, (b) YouTube videot vaadates.

Eelnevast tulenevalt saab pilgu trajektoori jälgimist kasutada keskkondades, kus on rohkem tekstisisu. Kuna RangeForce laborite puhul kuvatakse enne labori algust taustaloo ja ülesande kirjeldus ning tekstilisi juhiseid on antud ka labori sooritamise ajal, oleks võimalik jälgida, kas kasutaja pilk liigub paremalt vasakule, kui parasjagu on aktiivne tekstilist sisu sisaldav aken. Kui trajektoor on ebaühtlane ja hüplik, liikumata kordagi horisontaalsihilises joones, on alust arvata, et kaamera ees viibiv isik ei tegele teksti lugemisega. See võib tähendada, et ta jälgib kellegi teise sooritust ilma ülesande juhistesse süvenemata või kasutab hoopis mõnd muud graafilise sisuga keskkonda, nagu YouTube.

### Sisendseadmete kasutus

Kõik ülesande lahendamiseks vaja minevad käsud olid ette antud juhisaknas. Ilmnes, et uuringus osalejad kasutasid käskude sisestamiseks nelja eri meetodit ja nende kombinatsioone:

* Käskude kopeerimine ja kleepimine hiirega.
* Käskude kopeerimine ja kleepimine kiirklahvide ehk klaviatuuriklahvide kombinatsiooniga.
* Käskude sõna-sõnaline ümber trükkimine konsooli.
* Käskude osaline trükkimine konsooli koos nende automaatse lõpetamisega tabulaatorklahvi (*tab*) abil.

See annab laialdast infot kasutaja eelistuste kohta ning võimaldab osalejatel vahet teha ainuüksi valitud käsusisestusmeetodi põhjal. Kui soovida suurendada analüüsiks kogutud andmestikku, võib trükkimisdünaamika järgi kasutaja tuvastamiseks keelata hiire ja klaviatuuri kopeerimise ja kleepimise funktsioonid. See sunnib kõiki sooritajaid käske manuaalselt terminaliaknasse ümber kirjutama. Tabulaatorklahvi keelamise vajadust ei peeta oluliseks, kuna selle kasutamine või mittekasutamine on kasutajaspetsiifiline, mistõttu antud aspekt võib olla üheks faktoriks, mille alusel kasutajate trükkimisstiile eristada.

Kuigi kõik osalejad olid pädevad arvutikasutajad, vaadati soorituse ajal trükkimist alustades mõnikord siiski klaviatuuri suunas (vt Joonis 22). Vaatlejad, kellel polnud võimalik klaviatuuri ega hiirt kasutada, videos toimuva trükkimisprotsessi ajal laua suunas ei vaadanud. Klaviatuuri suunas unustasid sageli vaadata ka ennustajad, kelle ülesandeks oli ettekujuteldavat kaitsesüsteemi petta, kuid see võis tuleneda ka sellest, et nad ei omanud põhjalikku ülevaadet potentsiaalsetest kaitsemeetmetest.

![A person sitting at a table

Description generated with high confidence](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDoRXhpZgAATU0AKgAAAAgABAE7AAIAAAAKAAAISodpAAQAAAABAAAIVJydAAEAAAAUAAAQzOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEV2YSBNYXJpYQAABZADAAIAAAAUAAAQopAEAAIAAAAUAAAQtpKRAAIAAAADMTEAAJKSAAIAAAADMTEAAOocAAcAAAgMAAAIlgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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n2PNo57TyxHEG46Bsf41VlsYySy5AqSW1FnI6t86q5USJ0OOOK6221fwtqdisV3anTrtAAZI1LI+PbOQfzq+XsTd9TjIrGIEmdyF9Aea29NEA0+MJuxlsf99GuxsvC/g65kiFzry5cBlSNDk9OCK1I/AelQJstr9jECShMBHBOf60rBzHk/hmVz4n08FiczKDXf3JMd24OcmVufXmvO/DX/ACM2n/8AXdf516DrH7rVoo17sT+taw2Mqm6LCHJ461Mq7jjtUEX04q3HyvNKwh8aYwO571biX9KgiHPFW4/u0WHcswpnBrVitVkt+fSsuI4UVftpysqAn5SaTRpAyZR5TFOwqi9zCrYYjNbWqWwUMydK5C6eIuQ4bOaiR6NKTsaa31tuwHX8xVuO9jZfkYH6GuYWyt5CzAEH61XM62c22Nju9M1GtjXm7nZ+flQRTTe+UM/nWfpc5ugM5B6H2pdWiZF2p1P/ANehXkVJxihZ/EaRsVihaU9OOKINTv5mDSMIkPOAOlcqupG0uit1C+M/eArYtNaju5Fht7eR89WxgCq5WYc8WdhYzfaCFaTeSOnFbF3bRxxIQoznFR6NpkUcKvsw2Oa1LiFZQqMOM5wKzkhp66nlvjC3lOqyuFLKgA4H3QAOtdp8HF/dagX67gP0FdU3h9Jly8KsSOdwzVJxN4WLPp2ktOZyAyxfLjHfpVRWljkm7z5jsmOahkIxyK48+M9WX7/hu7/Bv/rVEfGuoH7/AIevR/n6VXKyeZHVTds+lZlzMQ3BxzWFJ4zuyDnQL79Kx9Q8cGBwLjSLyNjyA20Z/WnZi5kdd4I+IaX6i0vQFmUA7c/eX+8nqPbqK6HVPiH4d025WCW6MsmcN9niaTy/97HSvlSz8RXOkawgDM0IcEBThkP95T2Pt3r134b+ILTT7QW90Y5Ptchn8yTB8x25YZ7HNS4rcam9j1B/G+gmIOt6GHtGxP8AKuS8SfEK21PSr3TvDkkyag4CpJJCUXk8jJ9u/vXfW0tpc2qvbxR49NoyKz9S0y2vFZ/LVXXvtrP3exo+bufJevW1xo8r2U8ZhdD9xxx9R6j3rJiWC4TBISTpweDXt3j3w/b3q/6dEylRhJlGSorx/VvDVxYKZYP30A/jUf0rVO5i4lJJrjT5/vFWHI5rq9K1u5fTYmaaQk7uS5/vH3rh3eQud7En3NdDpJH9lxZ/2v8A0I1SZPKUvDds/wDwkdgxHAnUn867TxbK8GuI8YLbBnFW9A0L7FJAZ1V5FYEsD710d9Z28tyWuLdX9yAa0hZIxm7nn3/CSyRr/qMt6Usfiy4H/Lm1ekwaDYSKrC2jIIH8NXo/D2n9PssWMc/KKV0HzPL18W3K8/Ym/OrCeMZ1x/oL/nXqSaBp+4f6HCfTEYqwnh7TiQfsUGf+uYouuxVmeWL4zn4/0Fvz4rTtfFTTJue2ZQvU5r0hfDenORmzh+mwVch8Nab3tIv++BRoVZnK2Ew1G2SV0IVh/FWNr2jqyu0K/MehH0r0jW9LSLSQ8CBPK6ADtXDTTl8g1D7noUXeNmecvpOqrIVjnbbnB57VctNFNsPMlJeQ8kk12BReSBk1QvRiM0uY2jSVyHRR5V1g/wAR/wAK6ufS47yNTjkDrXK6YM3AYdv/AK1dvBxaB+pH+FJFzimrHPS+GbaViJUDfWtHT9HtbRhshUH1FPe7xcFCPrVpH3DOKd7kxhE1IXCqNvHtWzolgL+4Msn3IjyP7xrnFkyQBXfeFLXZpDP3kcnH6VBhU0LDQANgLxUscAOAetTMh3YFSxpgcdaZzFY2SHoMVG9nGOCP1q/gY6/hTWXK4osBjz2Sc8e9cv4j0G31GzcyLh4QXRvpyR9K7l4+x5HrWVrNsP7JvHH8NvIc/wDATQB8feSJNfijPIZufyJrZ02cpYhZPnhnUb09/Ue/FYc1x9l1vzwu7YrYGe5Uj+taWm3MT6fCjHDIMVb3M9D13wj46kszEl5PujOFE7dvZ/8AGvTp/EGmpphur6eK2UEAtI4Az2we9fM9pdJbzAmT5G4cY4Iqvc+IxeeKdLtLuaSfSbGcMIH+Yc43cd+mPpU8qZSlynut/wCL/CdzFIJ9TtyqjnOefpxzXKOnhvUY5J9LvYWTnchP9DXUC48KXdrC1xpNnKsqb0kigUgj8OlV3XwdHkJpMcZbk7IQKjRF3bPCPGUWix3X/EqbMmcOqLhB71DpXGmRf8C/9CNe3zQ+CpD+80xD6nyxUPleFl4gslWMdAIhT5kTZmdbWsiyKxfv0xWh9mEknJyD2pqrtwFGTkc1fhjwQTXUkcSaJbeHZtC9KvRx9MU2JflXA7Vbij6AVBaFiiG4H0q3GoJwKWK3JIAHWr8NgSRkUWLIUjz93ircULHGBx2q3DZbcelW44VT60FIzrq38yzdG6MvIryrV7M2t44I6HivZ5E8yMiuL8Y6GVtxcoM9mpG9KbhK5wIPGO9Ub5d8LY61cclM57Gq03zD2NZeTPTi9CLTtsCj2NdDHqscFuWkbaMc1x0lpJFOJIXIOa2LCEXDj7VhlHQdqSJlLQuS3SXN2JIfTk461owyZABqt5cMRwgwv0qaPaPuniqaMnNs07cbgM16xplv9i0uCLGCiDP1715jonki+ha5JEQYM2OTXpI1Wykh3C5j2jrk4x+FJnPUbbJ8+1SI200xMSxh4iGVujKQQacI2A6U0jIViD0ptHTrRTAa33TWRr7mPw3qTjtaS/8AoBrXYZBrA8XSeV4O1Zielq/8sUrCufIEt0lrrEsrxiUGGWPaw6M0bKD+BIP4V0y/D29fwjpetadcLIt5CXaNhjawYjaD+FcdqCNJeTMvIQZPsM17f4C1GbWPhtp2haTafartQ4llcbY7Ybyck+uOw/XpWhn01PF7+G80+cw3NuyP7r1qhazyQX0c0S5kR8hcdT6V7Xe+HDpGoyLdIss+eZGGQfcZrzHwxYtceMGfbmO2d3c+nOB+pqHuUlZBNrmoR2zG0nmtY2bPlKcbTjn86zl13WJZAFvbl27AOTmuk8bspmiA7J/WsPwom7xAvosbH9KAuQSaxrD7t9xcfJjdkkY+tdzYwy/YkzLI3Xkt7mub1OSO5l1kR7SEiR1Yd8NzXRWfiG3e1Vo4ZHXJw2OvJqegXPTUtcLnFW4LbcB7gVcaFViOR2zVqwiR404zwP5V1X0OJJha2GcZHStSGxVQM1JbxbiFQVu2Wk5USTHb3ApKLZpsUYLHpheKvxWEox8v41sQ+X5fCgBetOeVdo7VfKNMz106Urkso+pqaPTx/E2T6YqxuG3dniliYlix7dKfLoWmONjDFaliMtg4zXK6jbi4tnimYsrDoa62eQPbkexrkL64CBvaueonY6aNmzy3WtM+yXkkYbcAetYMwaNTgZPauj8QSl5mkVue/vXOm4WUkNw1ZSOuL0Me6nvgcxooHr1qNLnUnwBJtx3UAVrtCSx5oW3+YbiaNS+YitYrkgG5uZH9FzW1ahuMmoIYYkGTVmFgxwvFUYSkbdqMQhlPfJroLdz5YINc3DKI7fnuK17abZGoLc4rNrUlM7Dw/fGOOSLsCCB6Zro4NSQSCOUAq3QmuI0abLysOnA/nWpNMWAOeo4/Cu6Ebx1OScrSdjr2tIJk3ISv61A+ly4zGysOwrN0rVvtFqCWw68OK0Y9S8uRecg1DpsakULiJ4mxICPrXM+OZtngfV8HH+jEfqK9AkaC7TbIu7I456VxXj/w1e3nhHUYdKVrlpI/ljUfN1zjHeo5Xcd9D4uvpCLqVV4DHB/Ovpz4S20dh8LtKKqFa4VpnI/iJYjn8BXz0/hHWLu7v1gtGZ7JfMnjH3lBOOnU47+lfRHgF1X4eaIqcBbUDGe+TmiUWr3JUr2sVviZc21h4SutVbaLi2AEOf42Y4C/rn8K8s8Lac+m6e0l0MXN4RNJxgj0H6k/jW/8VPEMP/CZaDolyu+yhnjurpD0ck4UH6DP51teK9Gzu1CA4AOJVA/WotoU2eUeM33XSAf3f8ax/D0Ms2pukTbMoQ79wvtWh4sYfawoOSAP61R8PXEVo11cTMBsj4z35pXRO5oa8iW94kNkVXzLZo5AfQc/nxXQ6BNBHoFmoQDEQzj17muJu5o7y3RxNuu5ZCWAHQE4A/LFdHp86Q2McYbAXIAx7mhvQGe/MRKm0dx+VW7CAosca8ngZFUYT8w/Kuj0m2ABkP3guRntxXTGN9Djuauk20cMv7zBfA69q1LiTyoCRWKsuyRZgOc4NSalqIFsADlm4610qGoubQvwTYsnYnrR526DOecVR8wxaXyeWA4zT4ZM2/uR0qrDiy6bjMYXsPepopSwwDj8azkbKhR+NWozsYVLVjWLLqndGR6Vxeuq0U8i84NdYJcSFQeD71ieI7TzY/MUc9DWM43RrTlaR5NqZPmOG9TWG8QPzDueOK6XXrN42aRVOOjDFc/nvXI43O6MiEM698j0NP8AOJIGMUmDTTxyP1pWaKbT2JlJY4q9bkIo+tUrVWdvx9K0AnlqD3qktDGWhaiYyuIwTjvWtFuPfis+yg2rvPU1pbsKdo5xwB3p2uJG5ogIsnf++5/Sr6z+bbk9WQ4IqOxhW2tYojztX5vrUFm+Z7hB0ODXdFWRxSd3cmsbw2188ecI9apvXDL9a5i9Yxzq/wDntWgbkvbxyKeT1osO51cN6QAc8EVdjv8AKj5vpXLLdfuVOeSKngvTuA/KocbjTOX+JHhV4vM8W+Gt1vqECEXSxAfvYj944xjNeLwa7r2l+H5LrT9TW3soHOLXzVVuvO1Tz37e9fTX2rFvIZAHQgqyHkMMdCO9fOfxY+HU2mXkWo6GjPYXcmzy93+qkPRfoexNZyi2hJ2dzzXWdaute1k6heyuZcKu5m3Ebelac/jrWJYjE15Oy4x80rHP61dsfhpqVwA15NFbA9Vzub9K3YPhrpkCA3U09w/oMIK5rGvMcDfXD3EUUkrFnYZJNZgVjnaCfoK3fEkUVtqr29unlxRfKq5zgD3qnpyAwyZxye9JgmN06BllNw6/JGM1q6e5ksUcnqW/maoTyeRZMFOC54FXtK/5BkX4/wDoRoHHXU+lLCMO4PpWxDeG2nQkkqx2kUUV6NNaHmX1LkspG7Gdp5FU2k825QHkZ6GiitYjNHUJsRpEvHvUsRxbiiijoUtx1tKTIV9OlXPMNFFJo1jsRySFWDjoDT7thcW5UjqO9FFTuUcTqdpG0kisB78Vx+paSsG548Bc9PSiiuJ6SO1O8UzKEOcjvSPAV64NFFVZDT1LNlGMFu9W4V8+fB5VT09aKKkGaisiKAO3tV3S0FxdrnpH82PftRRV04pyIqtqJ0UZIO3saoWr7dTYeuaKK6mcguooSCR71Xs5S1u6enIoopAXYZi1tj0qaCY5yeg96KKTGi7Lc/6IF6bjk1Q1K2h1W1exu13QTJsYDqPQj3BwR7iiipsLqeXTPc6bqlxpt2264tX2lh0cdQ34ika8ldTkiiiuafxGiPI/EchfWLhjyd5602ys5JNHM0eAd574oorJ7lX0Kt6T5QVv4eK1NKP/ABLIvx/maKKT3Lhsf//Z)

Joonis . Klaviatuuri vaatamine trükkimisel.

Kuna tegemist oli osalejate jaoks võõra ja harjumatu arvutiga, ei saa üheselt väita, et klaviatuuri vaatamine trükkimise algul toimub igakordselt. Kinnitamaks, et kõik sooritajad vaatavad ka oma personaalarvutis trükkides alati vähemalt korra sisendseadme poole tuleb teostada lisauuring. Samas võib antud uurimuse tulemustele toetudes pidevat sisendseadme pilguga eiramist kasutada eksamikorra rikkumise riski tõenäosuse suurendamiseks.

### Muud tähelepanekud

Võiks eeldada, et neil osalejatel, kes läbisid enne vaatluskatse ja seejärel labori soorituse, kulus labori lahendamisele vähem aega, kuid antud uurimuses osalejate puhul see alati nii ei olnud. Sageli kiirustati laborit lahendades, mistõttu jäid mõned asjad kahe silma vahele ning ühel osalejal kulus vigade korrigeerimise tõttu labori sooritamisele lausa kahekordne aeg kui teistel.

Esines mõningaid erinevusi labori vaatlejate ja sooritajate käitumises. Kui sooritajad olid enamasti aktiivselt ülesandele pühendunud ja vaatasid harva ekraanilt kõrvale, siis vaatlejad tegid seda sagedamini (vt Joonis 23) ning eriti siis, kui vaatluskatse oli pärast soorituskatset. Vaatlejad olid tihti toolis tahapoole nõjatunud, kuna neil puudus vajadus kasutada sisendseadmeid. Sooritajad seevastu istusid kaamerale lähemal ja olid püstisemas asendis.

![A person looking at the camera

Description generated with very high confidence](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDoRXhpZgAATU0AKgAAAAgABAE7AAIAAAAKAAAISodpAAQAAAABAAAIVJydAAEAAAAUAAAQzOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEV2YSBNYXJpYQAABZADAAIAAAAUAAAQopAEAAIAAAAUAAAQtpKRAAIAAAADODMAAJKSAAIAAAADODMAAOocAAcAAAgMAAAIlgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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Joonis . Vaatluskatse ajal ekraanist eemale vaatamine.

Kui soorituskatseajal olid osalejad enamasti keskendunud, siis kellegi teise lahendust vaadates ja Postimehe ning YouTube’i veebilehtedel ringi navigeerides varieerus osalejate miimika suuresti (vt Joonis 25). Emotsioonid võisid olla üle pingutatud, kuna uuringus osalejad teadsid, et nende tegevusi salvestatakse. Soorituskatse ajal olid osalejad pigem keskendunud ning mõnikord isegi frustratsiooni väljendava pilguga. Seetõttu sai kinnitust oletus, et miimika võib olla üheks kaitsemeetmeks, et vältida kehastusrünnet ja tuvastada olukorda, kus kaamera ees viibiv isik tegeleb tugevalt kõrvaliste asjadega. Samas ei ole võimalik üheselt välistada, et kandidaadi miimika ei või RangeForce sisseastumistesti ajal laialdaselt varieeruda, mistõttu ei saa ainuüksi näoilme muutumisest resoluutselt eksamikorra rikkumist järeldada.

![A person looking at the camera

Description generated with high confidence](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDoRXhpZgAATU0AKgAAAAgABAE7AAIAAAAKAAAISodpAAQAAAABAAAIVJydAAEAAAAUAAAQzOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEV2YSBNYXJpYQAABZADAAIAAAAUAAAQopAEAAIAAAAUAAAQtpKRAAIAAAADMDYAAJKSAAIAAAADMDYAAOocAAcAAAgMAAAIlgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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![A person looking at the camera

Description generated with very high 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person sitting at a desk

Description generated with high confidence](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDoRXhpZgAATU0AKgAAAAgABAE7AAIAAAAKAAAISodpAAQAAAABAAAIVJydAAEAAAAUAAAQzOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEV2YSBNYXJpYQAABZADAAIAAAAUAAAQopAEAAIAAAAUAAAQtpKRAAIAAAADODkAAJKSAAIAAAADODkAAOocAAcAAAgMAAAIlgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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![A person smiling for the camera

Description generated with very high confidence](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDoRXhpZgAATU0AKgAAAAgABAE7AAIAAAAKAAAISodpAAQAAAABAAAIVJydAAEAAAAUAAAQzOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEV2YSBNYXJpYQAABZADAAIAAAAUAAAQopAEAAIAAAAUAAAQtpKRAAIAAAADNjkAAJKSAAIAAAADNjkAAOocAAcAAAgMAAAIlgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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Joonis . Erinevad reaktsioonid vaatamise ja muud tüüpi katsetel.

Üks katsete ajal üksinda ruumis viibinud osaleja rääkis valjuhäälselt omaette nii soorituse, vaatluse kui ka Postimehe ja YouTube’i veebilehe külastamise ajal, väites hiljem, et tegemist on tema tavapärase kombega. Ülejäänud osalejad olid katsete sooritamise ajal üldjuhul vait, aeg-ajalt esines vaid köhatamist, haigutusi või nihelemisega kaasnevaid helisid. Sellest tulenevalt saab kinnitust oletus, et kui kaitsemeetmena on kasutusel ruumihelist inimkõne tuvastamine, tuleb kandidaatidele selgitada, et testi sooritamise ajal peab ruumis valitsema vaikus.

Kuigi katses osalejatele ei olnud eelnevalt võimalikke ründeid tutvustatud, toodi pärast katseid uurimuse tausta selgitamise peale esile ründevõimalus, kus vahetult arvutiekraani alla on asetatud lisaseade, nagu mobiiltelefon, tahvel- või sülearvuti, mida kasutatakse sisseastumistesti ajal kõrvalise abi saamiseks. Lisaseadme poole vaatamist on kerge segi ajada klaviatuuri vaatamisega, mistõttu saab püstitada kaks väidet:

* kui kandidaadi pilk on suunatud alla, kuid sisseastumistestiks kasutataval arvutil puudub klaviatuurisisend, on võimalus, et infovahetuseks kasutatakse vahetult ekraani all asuvat lisaseadet;
* kui ruumihelis on kosta klahvivajutusi, kuid arvutil puudub klaviatuurisisend, kasutatakse suure tõenäosusega klaviatuuriga lisaseadet.

# Progreosa

# Küberkaitse eriala sisseastumistesti jaoks sobiva süsteemi kirjeldus

Käesolevas peatükis kirjeldatakse Tallinna Tehnikaülikooli küberkaitse eriala sisseastumiseksami kaitsesüsteemi üldist toimimist ning süsteemi funktsionaalsed ja mittefunktsionaalsed nõudeid, võttes arvesse eelpool esitatud ründeid, võimalikke kaitsemeetmeid, varasemalt tehtud töid ning praktiliste katsetuste tulemusi.

Tegemist on klient-server lahendusega, mis jaguneb üldpildis kaheks. Kandidaadi arvutisse paigaldatav programmi näol on sisulist tegemist lukustusbrauseriga. Programmi käivitades blokeeritakse lokaalses masinas võimalused avada teisi rakendusi, sealhulgas klahvikombinatsioonide (nagu Ctrl+Alt+Del) abil kaitsesüsteemi sulgedes. Tänu sellele on takistatud keelatud abivahendite kasutamine kandidaadi arvutis. Rakenduse avamisel kontrollitakse lisaekraanide olemasolu ning seda, kas rakendus käivitati virtuaalmasinas, mispuhul rakendus teavitab kasutajat tingimuste rikkumisest ja sulgub.

Lukustusbrauseri edukal käivitumisel palutakse kasutajalt autentimist. Kui kandidaadil kasutajakontot ei ole, on esitatud võimalus see luua. Konto loomisel nõutakse kandidaadilt pildiga isikut tõendava dokumendi esitamist, millel olev dokumendifoto on hiljem aluseks näotuvastusele. Eduka sisselogimise korral palutakse kandidaadil salvestada video, mis annab põhjaliku 360-kraadise ülevaate keskkonnast, kus sisseastumistesti sooritatakse, ning suunatakse kandidaat RangeForce keskkonda, kus tal on võimalik sooritada sisseastumistesti laboreid. Samal ajal hakkab tööle kasutaja pidevtuvastus, mis jälgib kogu süsteemi lahti oleku ajal veebikaamera, sisendseadmete (klaviatuur, hiir) ja mikrofoni abil kasutaja nägu, trükkimise dünaamikat, hiire kasutusviisi ja riiete värvi, tuvastamaks kehastusründe esinemist. Välise abi kasutamist kontrollitakse silmade fookuspunkti, ruumiheli ja ruumist esinevat videovoogu jälgides. Seansi jooksul edastatakse kogutud andmed serverile, kus toimub nende salvestus ja analüüs.

Igale kandidaadile on määratud usalduskvoot, mis on süsteemi sisenedes 100%. See tähendab, et süsteemi sisenemise hetkel eeldatakse, et kandidaat ei riku eksamikorda. Kui kaitsesüsteem tuvastab eksamikorra rikkumise, märgistab ta antud koha salvestatud videos ning vähendab kandidaadi usalduskvooti. Kindlat piiri, millest allapoole langedes takistatakse kandidaadil sisseastumistestide sooritamist, ei ole, kuid usalduskvoot kuvatakse hiljem kandidaadi soorituse kohta käivate andmete juures ning ülikooli esindajal on sellele vastavalt võimalik teha otsus sisseastumistesti läbimise kohta. Kuna eksamikorra rikkumise vastane kaitsesüsteem alustab aktiivselt tööd sisse logimise hetkest, on oluline, et kandidaat tegeleks rakenduse tööl oleku ajal ainult sisseastumistesti lahendamisega. Seetõttu tuleb kandidaati kindlasti enne sisse logimist informeerida eksamikorrast ja tingimustest. Kui kandidaat soovib sisseastumistesti hiljem jätkata, on võimalik andmete kogumine lõpetada ja kaitsesüsteem sulgeda sellest välja logides.

Ülikooli esindajale mõeldud alamosa võimaldab sisseastumistesti veebirakenduse vahendusel hallata. Esindaja sisse logides kuvatakse rakenduse avalehel nimekiri lisakontrolli vajavatest testitulemustest ehk nendest sooritustest, mis jäävad allapoole teatud piiri, mille ülikool on kandidaadi usalduskvoodile määranud. Läbimispiiri on ülikoolil võimalik jooksvalt muuta. Iga soorituse juures on välja toodud videosalvestus kogu sooritusest, kusjuures süsteemi poolt eksamikorra rikkumisena tuvastatud hetked on eraldi märgistatud, hõlbustades nendeni navigeerimist ja nende manuaalset kontrolli. Soorituste manuaalne üle vaatamine ei ole vajalik, aga on soovi korral võimalik. Lisaks on veebirakenduses kõigi kaitsesüsteemiga liitunud kandidaatide nimekirja sisaldav alamleht. Võimalik on navigeerida iga kandidaadi individuaalsele profiilile, kus on esitatud usalduskvoodi keskmine, andmed kandidaadi kohta (sealhulgas fotojäädvustus isikut tõendavast dokumendist) ning viited kaitsesüsteemiga tehtud sisseastumistesti laborite sooritustele koos märgistatud videolindistustega. Kui usalduskvoot on liiga madal, on ülikooli esindajal intervjuuvoorus küsida täpsustavaid küsimusi sisseastumistesti sooritamise kohta.

Kaitsesüsteemiks on kandidaadi arvutisse installitav rakendus, kuna nii on kõige suurem kontroll lokaalses masinas toimuva üle. Veebiplugina kasutamine ei ole antud ülesandepüstituse puhul piisav, kuna ei võimalda blokeerida lokaalses masinas avatavaid rakendusi. Oluline on, et sisseastumistesti kontrollitud lahendamiseks ei oleks kandidaadil vaja eririistvara. Välja pakutud süsteemi korral on oluline vaid arvuti, klaviatuuri, hiire, veebikaamera, mikrofoni ja kõlarite olemasolu.

Klient-server arhitektuuri kasuks otsustati lootuses, et nii on kandidaadil vähem võimalusi kaitsesüsteemi toimimisele vahele segada, selle töötamispõhimõtteid muuta ja niiviisi ülikoolile valeinfot edastada. Samas tuleb tõdeda, et ükski programm ei ole kunagi kõigi rünnete eest kaitstud. Lisaks andmeanalüüsiga tegeleva süsteemi kaitsmisele vähendab klient-serveri arhitektuur kandidaadi arvuti koormust, teostades isikutuvastuseks ja andmeanalüüsiks vajalikud operatsioonid ülikooli kui teenusepakkuja ressursse kasutades.

**Jõudlus: Videovoo pidev ülekanne serveripoolele koormab ühendust. Parem edastada perioodiliselt pildistatud kaadreid ja analüüsida neid, sest kui ajaraam on piisavalt väike, ei jõua midagi kriitilist juhtuda.**

## Funktsionaalsed nõuded

Eksamikorra rikkumise vastase kaitsesüsteemi funktsionaalsed nõuded on järgmised:

* Süsteem peab käivitudes paluma kasutaja autentimist. Kasutaja tuvastamiseks kasutatakse **MILLE ja MILLE ja näotuvastuse** kombinatsiooni.
* Kui kasutajakontot süsteemi andmebaasis ei eksisteeri, peab süsteem võimaldama uut kasutajakontot luua.
* Kasutajakonto olemasolul peab süsteem võimaldama kasutajal sisse logida.
* Süsteem peab võimaldama välja logimist.
* Süsteem peab kasutajakonto loomisel salvestama fotojäädvustuse kandidaadi pildiga isikut tõendavast dokumendist. Dokument võib olla süsteemi sisestatud kas sisse skannitud failina või kasutajakonto loomise ajal veebikaamera abil pildistades.
* Süsteem peab enne sisseastumistesti alustamist kandidaadile kuvama nimekirja testi tegemise ajal keelatud tegevustest.
* Süsteem peab enne iga sisseastumistesti sessiooni algust kandidaadilt nõudma ruumist ja töökohast 360-kraadist ülevaadet andva video lindistamist.
* Süsteem peab võimaldama RangeForce keskkonna avamist ja keskkonnas laborite sooritamist.
* Süsteem peab sisseastumistesti laborite sooritamise ajal salvestama veebikaamera videovoo, ruumiheli ja sisendseadmetelt (klaviatuur, hiir) saadava info.
* Süsteem peab laborite sooritamise ajal teostama kasutaja pidevtuvastamist.
* Süsteem peab näotuvastust kasutades sisseastumistesti sooritamise ajal võrdlema registreerumisel salvestatud dokumendifotot veebikaamerast saadava videovooga kasutajast, tuvastamaks isikute vahetumist testi tegemise ajal. Kui veebikaamera videovoos esinev nägu erineb salvestatud dokumendifotol olevast näost, peab süsteem olukorra märgistama kui kehastusründe.
* Süsteem peab veebikaamerast saadavas videovoos tuvastama olukorra, kus kaamera vaateväljas on rohkem või vähem kui üks nägu. Kui nägusid videovoos ei ole, peab süsteem olukorra videolindistuses märgistama kui kandidaadi lahkumise soorituse ajal. Kui nägusid on videovoos rohkem kui üks, peab süsteem olukorra märgistama kui kõrvalise isiku viibimise ruumis.
* Süsteem peab veebikaamera videovoo abil tuvastama muutusi kasutaja näoilmes. Kui miimika erinevus keskendunud näoilmest on liiga suur, eriti kui kandidaat naeratab pidevalt, peab süsteem olukorra märgistama kui kõrvalise tegevusega tegelemise.
* Süsteem peab veebikaamera videovoo abil tuvastama muutusi kasutaja riiete värvis. Kui kasutaja keha ehk näo all olev ala muudab värvi, peab süsteem olukorra märgistama kui riiete värvi muutuse ja potentsiaalse kehastusründe.
* Süsteem peab veebikaamera videovoo abil jälgima kandidaadi silmade fookuspunkti ja pilgu liikumist. Kui pilgu liikumine ei ole vastavuses kursori liikumisega ekraanil, peab süsteem olukorra märgistama kui kehastusründe ja kõrvalise tegevusega tegelemise. Kui ekraanil kuvatakse tekstisisu, aga kandidaadi pilk ei liigu kordagi horisontaalsihis paremalt vasakule või teeb seda liiga vähe või mujal kui tekstisisu kuvamise kohal, peab süsteem olukorra märgistama kui kehastusründe ja kõrvalise tegevusega tegelemise. Kui konkreetsesse ekraanipunkti liigutakse esmalt kursori ja seejärel pilguga, peab süsteem olukorra märgistama kui kehastusründe ja lisaekraani kasutamise.
* Süsteem peab analüüsima kandidaadi trükkimise dünaamikat. Kui trükkimisstiilis esineb märkimisväärseid kõrvalekaldeid kasutajaprofiili tavapärasest normist, peab süsteem olukorra märgistama kui kehastusründe.
* Süsteem peab analüüsima kandidaadi hiire kasutusviisi. Kui hiire kasutamise dünaamikas esineb märkimisväärseid kõrvalekaldeid kasutajaprofiili normist, peab süsteem olukorra märgistama kui kehastusründe.
* Süsteem peab tuvastama mikrofoni staatust, mängides kõlaritest helisignaali. Kui esitatud helisignaal mikrofoni sisendisse ei jõua, peab süsteem kasutajale kuvama hoiatuse ja takistama edasist tööd, kuni mikrofon ja kõlarid on sisse lülitatud.
* Süsteem peab ruumihelist tuvastama klaviatuuri klahvide vajutamise heli. Kui ruumihelis tuvastatakse klaviatuuri klahvide vajutamise heli, aga puudub klaviatuurisisend, peab süsteem olukorra märgistama kui potentsiaalse lisaseadme kasutamise.
* Süsteem peab ruumihelist tuvastama inimkõnet. Kui süsteem tuvastab ruumihelist inimkõne, peab süsteem olukorra märgistama kui kõrvalise isiku viibimise ruumis.
* Süsteem peab blokeerima teiste, kõrvaliste rakenduste avamist lokaalses masinas. Keelatud rakendused on näiteks ekraanijagamis- ja suhtlusprogrammid, brauserid, kalkulaator, tekstitöötlusrakendused ja lokaalse masina faililehitseja.
* Süsteem peab blokeerima klaviatuuri klahvikombinatsioone kasutades ekraanipildi jäädvustamise.
* Süsteem peab blokeerima klaviatuuri klahvikombinatsioone kasutades teksti kopeerimise ja kleepimise.
* Süsteem peab blokeerima hiire paremkliki abil teksti kopeerimise ja kleepimise.
* Süsteem peab blokeerima klaviatuuri klahvikombinatsioone kasutades süsteemi peatamise või süsteemist väljumise.
* Süsteem peab tuvastama süsteemi käivitumise virtuaalmasinas ja sulguma, teavitades eelnevalt kasutajat sellest, et süsteemi ei ole lubatud käivitada virtuaalkeskkonnas.
* Süsteem peab tuvastama, mitu ekraani on ühendatud arvutiga, kus süsteem käivitati, ja kui neid on rohkem kui üks, peab süsteem sulguma, teavitades kasutajat sellest, et lubatud on ainult üks kuvariekraan.
* Süsteem peab siduma kasutajaprofiili RangeForce sisseastumistesti jooksul sooritatud labori virtuaalmasina logiga.
* Süsteem peab kasutajaprofiiliga seotud virtuaalmasina logist tuvastama eelnevalt ülikooli esindaja poolt keelatud rakenduste ja tegevuste nimekirja kantud programmide avamise ja tegevuste sooritamise ning märgistama taolise olukorra kui keelatud materjalide kasutamise.
* Süsteem peab eksamikorra rikkumist tuvastades langetama kandidaadi usalduskvooti.

Ülikooli esindaja jaoks mõeldud alamsüsteem ei tegele eelpool mainitud kaitsemeetmete rakendamise, vaid sisseastumiseksami administreerimisega, ja peab võimaldama teostada järgmisi toiminguid:

* RangeForce labori virtuaalmasinas keelatud rakenduste ja tegevuste nimekirja koostamine;
* kõigi sisseastumistesti sooritanud kandidaatide nimekirja vaatamine;
* üksikkandidaadi info vaatamine, sealhulgas skannitud või veebikaameraga pildistatud isikut tõendava dokumendi ja testi algul veebikaameraga tehtud foto võrdlemine;
* kandidaadi sooritusest tehtud salvestise vaatamine, sealhulgas testi algul ruumist ja töökohast 360-kraadise ülevaate andva video vaatamine;
* lindistuses märgistatud eksamikorra rikkumise kohtade manuaalne kontrollimine;
* süsteemi poolt kandidaadi sooritusele antava usalduskvoodi vaatamine ja kinnitamine või muutmine;

## Mittefunktsionaalsed nõuded

Mittefunktsionaalsed nõuded süsteemile on alljärgnevad:

* Süsteemi kasutusliideseks peab olema kandidaadi arvutisse installitud programm.
* Süsteemi kasutajaliides on eriala õppetöö keelest lähtudes ingliskeelne.
* Süsteem ei tohi olla platvormispetsiifiline, see tähendab, et süsteem peab töötama kõigil enamlevinud operatsioonisüsteemidel, sealhulgas Microsoft Windows’il, Unix’il ja macOS’il.
* Süsteem peab töötama ilma eririistvarata, kasutades tööks ainult laua- või sülearvutit ja standardseid kergesti kätte saadavaid odavaid sisendseadmeid, nagu klaviatuur, hiir, veebikaamera, mikrofon, kõlarid.
* Süsteem peab andmete edastamiseks kasutama internetiühendust.
* Süsteem peab kasutaja pidevtuvastamiseks kasutama multimodaalseid meetodeid, st kombineerima näotuvastust, pilgu liikumise, trükkimisstiili ja hiire kasutuse analüüsi.
* Süsteemile peab olema hiljem võimalik lisada eksamikorra rikkumist tuvastavaid meetmeid, mida peab olema võimalik olemasolevatega kombineerida.
* Süsteem peab laborite sooritamise ajal kasutaja pidevtuvastamist teostama passiivselt, st ilma kasutajat segamata, veebikaamera ja sisendseadmete abil.
* Süsteem kogub kasutaja pidevtuvastuseks vajalikke andmeid 10-sekundiliste perioodide kaupa. Iga perioodi lõppedes käivitatakse uus kogumisperiood paralleelselt eelmise perioodi andmete saatmisega serverile.
* Kasutaja pidevtuvastuses esinevad pausid ei tohi olla pikemad kui 5 sekundit, vältimaks kehastusründe toimumist.
* Süsteem ei tohi lõpetada tööd, kui tuvastab eksamikorra rikkumise esinemise.
* Süsteem ei tohi võimaldada ligipääsu kõrvalistele, autoriseerimata isikutele, tagamaks isiku- ja delikaatsete andmete kaitse.
* Süsteem ei tohi säilitada ebavajalikke isikuandmeid.
* Süsteem peab olema võimeline edukalt toimima ka siis, kui kasutaja biomeetrilised faktorid on muutunud.
* **Süsteem peab olema suletud lähtekoodiga, raskendades kandidaatidel kaitsesüsteemi üle kavaldamist.**
* Süsteem peab klientarvuti ressursse kasutama ainult sellisel määral, mis on vajalik süsteemi elementaarseks tööks, kasutaja pidevtuvastuseks vajalike andmete kogumiseks ja nende edastamiseks serverile.

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Lisa 1 –

1. Alamülesannete lahendamiseks tarvilikke terminalikäske ja teooriat on TTÜ küberkaitse sisseastumiseksami puhul lubatud internetist otsida, aga tervikliku lahenduskäigu kirjelduse järgi testi tegemine langeb eksamikorra rikkumise alla. [↑](#footnote-ref-1)