Balancing new apps and privacy on the 5G Edge: *Opinions and views of Millennials*

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iGR

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Executive Summary

5G networks are the next step forward in mobile/cellular networks. They are characterized by very high downlink (and uplink) speeds, low latency, a flat network architecture with split control and user planes, and a services-oriented focus. 5G networks leverage a bevy of new technologies: fronthaul, CRAN, virtualization (NFV), software defined networking (SDN), edge computing, Massive MIMO, etc.

There are three fundamental 5G use cases and applications: enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable low latency (URLLC).

For this white paper, *iG*R has measured interest in several specific 5G services and applications that rely on at least one of the aspects of 5G functionality – enhanced mobile broadband (eMBB), ultra-reliable low latency (URLLC), or massive IoT. Some of the services, such as mobile gaming with Augmented Reality (AR) or Virtual Reality (VR), are not possible without 5G; others are simply enhanced by 5G functionality.

For this analysis *iG*R surveyed U.S. mobile users between the age of 18 and 35. Why this age group? This age group has grown up with wireless service and mobile apps and includes the largest number of adult smartphone and mobile app users. The reality is that these mobile users will be the future users of wireless and will drive the adoption of 5G.

Interest in 5G Applications

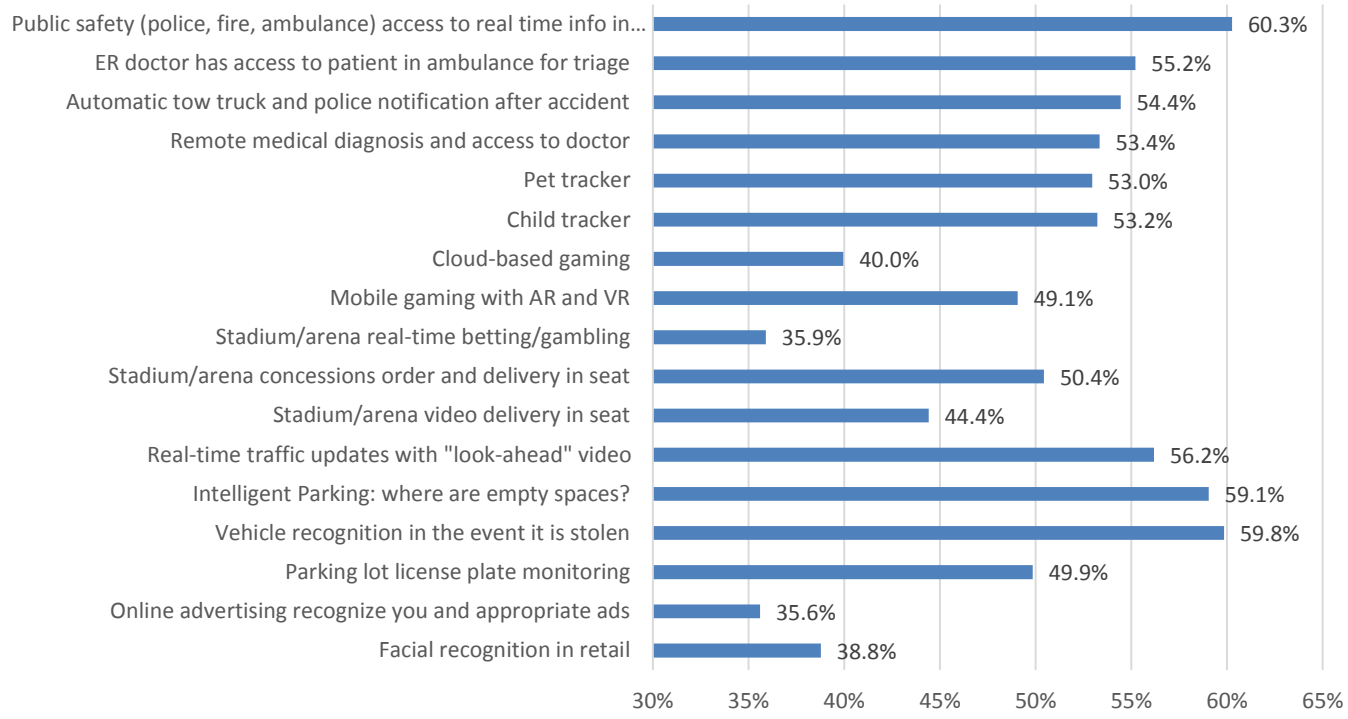
In the survey, the respondents were asked to rate their level of interest in 17 different 5G services or applications on a five-point scale from very interested to not-at-all interested. The services were in four basic categories: retail, transportation, entertainment, and personal/public safety.

To present the results of each application/service, *iG*R has summed the percentage of respondents that chose the top two responses (Top-2 Box) – very interested and interested, and these results are shown in Figure A.

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Figure A: Interest in 5G applications and services (Top-2 Box)



Source: *i*GR, 2019

Figure A demonstrates the overall high levels of interest in these applications among 18 to 34 year olds, the future users of 5G. More than half of respondents expressed interest in all of the transportation apps.

Several entertainment applications, which included gaming applications and three apps to be used in a stadium or arena, were presented in the survey and were interesting to a third to a half of respondents. And with a targeted market, the interest rate of these entertainment apps increases significantly; for example, 59 percent of males were interested in mobile concessions order and delivery in an arena, and 61 percent of males were interested in mobile gaming with AR/VR.

All of the personal and public safety applications were interesting to over half of respondents. And, with a focused market, the interest levels are even higher. For example, 65 percent of respondents with children were interested in the child tracker application, and over 60 percent of respondents with children were interested in the automatic tow truck and police notification application, as well as apps that give ER doctors access to patients in ambulances.

In general, the interest level in retail recognition applications for focused advertising was lower than that of transportation, entertainment and personal/public safety applications.

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Privacy Concerns

For those services for which the respondent was at least somewhat interested, *iG*R then asked how concerned they were about privacy when using the service/app – from extremely concerned to not-at-all concerned. To show the level of privacy concerns, *iG*R included the percentage of respondents who were extremely concerned or moderately concerned. The results highlight a reasonably high level of concern about privacy among potential 5G users.

Not surprisingly, the highest level of concern was expressed for applications that 'recognize' people. Over half of interested respondents expressed concern for the following three applications:

- Child tracker – 55 percent concern rate
- Facial recognition and targeted ads in physical retail stores – 49 percent concern rate
- User recognition for online ads – 49 percent concern rate.

Public safety applications that earned high interest levels among respondents still caused concern about privacy among almost half of respondents. For example:

- Remote Medical Diagnosis – 45 percent concern rate
- Apps that give ER doctors access to an ambulance for triage – 45 percent concern rate
- Police and tow truck notification in the event of a serious car accident – 44 percent concern rate
- Vehicle recognition in the event of a stolen vehicle – 44 percent concern rate

Even applications that seemingly would not create concern about privacy were in fact causes for concern in more than one third of respondents:

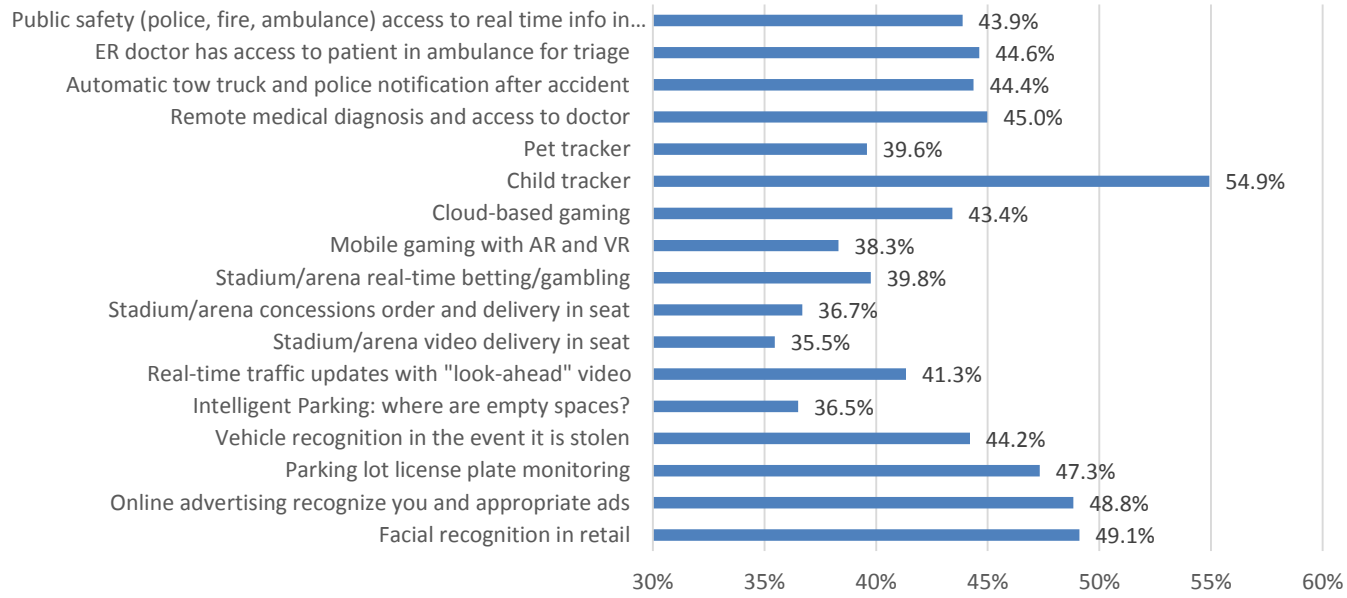
- Mobile video delivery in an arena or stadium – 36 percent concern rate
- Intelligent parking to find empty spaces – 37 percent concern rate
- Concessions delivery in an arena or stadium – 37 percent concern rate.

The following figure illustrates the above data. Again, the higher the percentage the greater the level of concern about privacy.

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Figure B: Privacy Concerns in 5G applications and services (Top-2 Box)



Summary

As this data shows, there is significant interest in the 5G-enabled applications and services. Once the services become available, this interest is likely to translate into usage. And with a focused market, such as targeting families with children, specific genders or specific age groups, interest rises. This again would translate into higher adoption. For example, 65 percent of respondents with children were interested in the child tracker application, and over 60 percent of respondents with children were interested in the automatic tow truck and police notification applications, as well as apps that give ER doctors access to ambulances.

But there is also significant concern about data privacy, especially with applications that involve facial recognition. This concern over privacy among interested 5G users demonstrates the need for a secure solution combined with the enabling 5G hardware and software.

Simply adding security as an afterthought will not suffice; consumers must feel secure when using these apps and services. For example, facial recognition imagery should be processed at the edge, as close to the camera as possible – and once actioned, deleted.

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What is 5G?

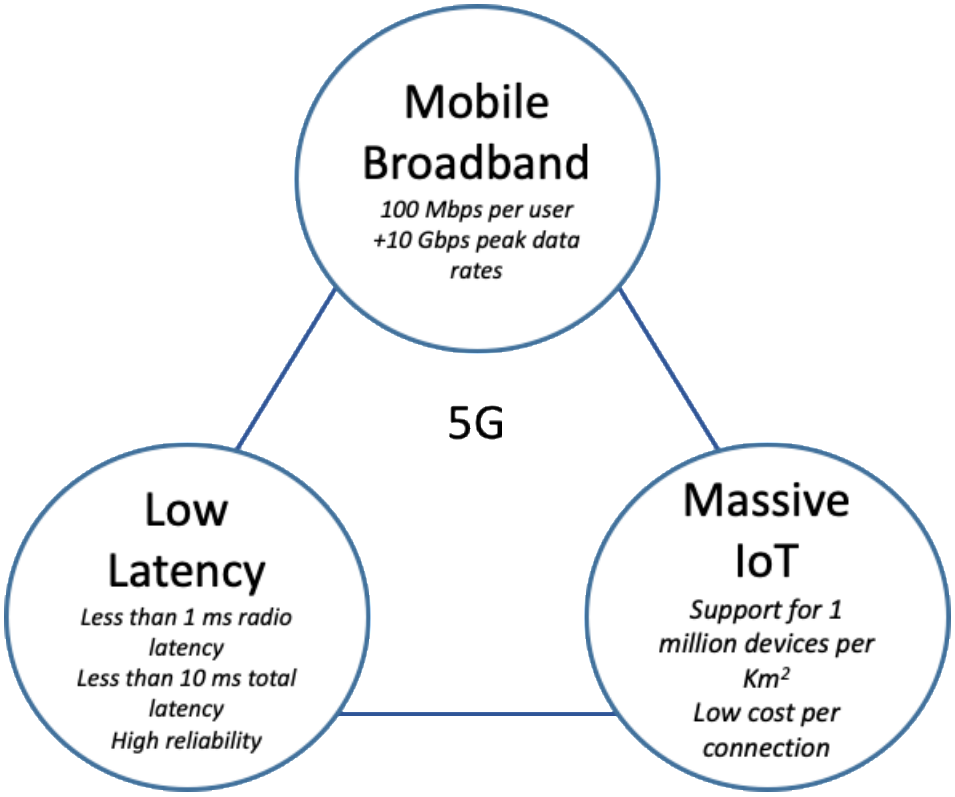
5G networks are the next step forward in mobile/cellular networks. They are characterized by very high downlink (and uplink) speeds, low latency, a flat network architecture with split control and user planes, and a services-oriented focus.

5G networks leverage a bevy of new technologies: fronthaul, CRAN, virtualization (NFV), software defined networking (SDN), edge computing, Massive MIMO, etc. Most initial 5G networks will use high-band spectrum – 28 GHz, initially, but the major U.S. operators have all said they would deploy 5G NR in their sub-6 GHz spectrum bands. Other operators in the world, notably Korea Telecom, NTT DoCoMo and China Mobile, have said that they intend to also deploy 5G in the 3.5 GHz band. In the U.S., this is the CBRS spectrum band. It, too, is on a path to 5G NR.

5G Use Cases

There are three fundamental 5G use cases and applications: enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable low latency (URLLC). The chart below shows the specifications for each of these fundamental capabilities.

Figure 1: 5G fundamental capabilities



Source: *iG*R, 2019

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eMBB

3GPP Release 15 is the first 5G NR standard. It is focused around Enhanced Mobile Broadband (eMBB) while also including some of URLLC. eMBB will deliver:

- Spectral efficiency: 3x improvement over values set for IMT-Advanced
- Peak data rates: 20 Gbps on downlink; 10 Gbps on uplink
- Lower power consumption in networks and terminals
- Lower latency:
    - One-way user plane latency is expected to be 4ms
    - Control plane latency: the 3gpp is targeting 10 ms. This is taking a device from idle to transmitting packets.

URLLC

5G NR introduces multiple physical layer changes that will enable 5G networks to deliver lower latency which is defined by the 3GPP standards in a couple ways:

- User plane latency (one way) of 4 ms in eMBB (Rel-15), but 1 ms in URLLC (Rel-16)
- Control plane latency of 20 ms (although 10 ms is encouraged); this is from the device idle state to the start of continuous data transfer (at which point the user plane latency target would kick in).

Reliability is defined in several ways:

- Capability of transmitting a certain amount of data within a time duration with high probability of success
- Reliability per node and control channel reliability
- Availability: Five “9s” probability that a given service is available (has coverage).

Massive IoT

Officially, Massive IoT is defined in terms of connection density:

- 4G LTE-Advanced: approximately 60k devices/km2 (this is Narrow Band (NB) – IoT)
- 5G: one million devices/km2 (or one device/m2) for urban environments in LTE-Advanced. And, terminals are required to operate for 10 to 15 years without changing or charging of batteries.

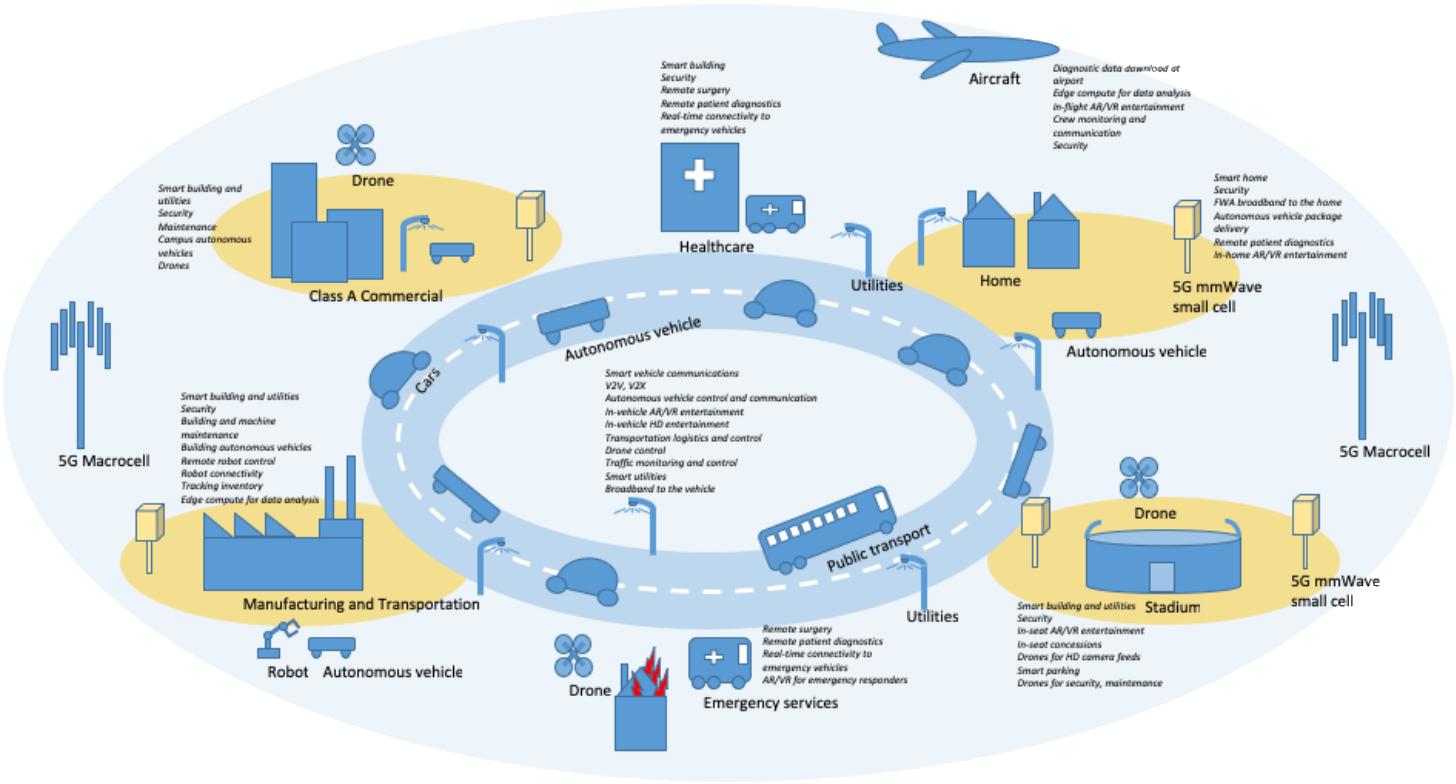
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5G Services and Use Cases

There are multiple examples of 5G-based services and use cases. The figure below illustrates some of the main applications and services planned for 5G.

Figure 2: 5G main applications and services



Source: *iG*R, 2019

Survey of Interest in 5G Applications and Services

For this white paper, *iG*R measured consumer interest in several specific 5G services and applications that rely on at least one of the aspects of 5G functionality just discussed – enhanced mobile broadband (eMBB), ultra-reliable low latency (URLLC), or massive IoT. Some of the services, such as mobile gaming with Augmented Reality or Virtual Reality, are not possible without 5G; other services are simply enhanced by 5G functionality.

For this analysis *iG*R surveyed over 1,000 U.S. mobile consumers between the age of 18 and 35. Why this age group? Simply put, this age group has grown up with wireless service and mobile apps and includes the largest number of adult smartphone and mobile app users. The reality is that these mobile users will be the future users of wireless and will drive the adoption of 5G.

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In the online survey, the respondents were asked to rate their level of interest in 17 different 5G services or applications – from very interested to not at all interested. For those services for which the respondent was at least somewhat interested, *iG*R then asked how concerned they were about privacy when using the service/app – from extremely concerned to not at all concerned.

To present the results of each application/service, *iG*R has summed the percentage of respondents that chose the top two responses – very interested and interested. Similarly, to present privacy concerns, *iG*R summed the percentage of respondents who were extremely concerned or moderately concerned.

Also included for each application are demographic splits by gender, age group, and whether or not the respondents have children living in their household.

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Retail

Facial recognition in retail is an application made possible with 5G. When a person enters a physical store, the store would have the ability to recognize the customer using facial recognition technologies, process and analyze the data quickly, and display appropriate ads targeted to that customer.

Store facial recognition

As shown in Figure 3 (see Appendix for all detailed charts), just under 39 percent of respondents found this application interesting. However, 47 percent of males did so. When comparing age groups, the youngest respondents (18 to 24 year olds) were the most interested, with 44 percent of this group expressing interest. Also, respondents with children living in their household were more interested than those without children – 44 percent interest compared to 34 percent interest.

Those respondents that showed some interest were then questioned about their privacy concerns, and as shown in Figure 4, almost half of these respondents (49 percent) were concerned about their privacy. Fifty-five percent of males were concerned, while only 43 percent of females were concerned. The oldest respondents (30 to 34 year olds) were somewhat less concerned than the younger respondents. There were no significant differences between those respondents with or without children.

Facial recognition of advertising

In addition to facial recognition in physical retail stores, 5G provides the ability for retailers to recognize customers and present suitable ads using online displays in the store.

As shown in Figure 5, almost 36 percent of respondents found this application interesting, compared to 39 percent for physical retail recognition shown above. Forty-seven percent of males were interested, but only 28 percent of females were. When comparing age groups, the youngest respondents were only somewhat more interested than the older groups, and the respondents with children living in their household were also somewhat more interested than those without children – 37 percent compared to 33 percent interest.

Those respondents that showed some interest were then questioned about their privacy concerns, and as shown in Figure 6, almost half of these respondents (49 percent) were concerned about their privacy. There was a small difference in privacy concern by gender, as 51 percent of males were concerned, while only 47 percent of females were concerned. The oldest respondents (30 to 34 year olds) were less concerned than the younger respondents, while those respondents with no children in their home were only slightly more concerned than those with children (50 percent compared to 47 percent).

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Transportation

Several possible 5G applications could benefit drivers. The first, parking lot license plate monitoring could be used to provide monitoring and increase the security of a parked car, at the airport for example, and to remind drivers where they parked.

Parking lot license plate monitoring

As shown in the Figure 7, almost half of respondents were interested in this application, with males being significantly more interested than females. The youngest respondents were the most interested, with 54 percent showing interest, while only 45 percent of the oldest were interested. Respondents with children were much more likely than those without to be interested in this service – 53 percent compared to 46 percent.

Approximately 47 percent of interested respondents had privacy concerns regarding the monitoring of their parked car. Males were more likely to have more concerns than females (56 percent to 41 percent). Aside from that, the data did not suggest significant differences when looked at by age group or by respondents with and without children. These results are illustrated in Figure 8 in the Appendix.

Stolen vehicle recognition

A related application is vehicle recognition to be used in the event a vehicle is stolen. With this application, if a car is stolen, the car is recognized by image recognition technology and the police are notified. Almost 60 percent of all respondents and almost 63 percent of males were interested in this service. Sixty-two percent of the two youngest age groups found this service interesting, while only 56 percent of 30 to 34 year olds did. Somewhat more respondents with children (62 percent) than respondents without children (57 percent) were interested. All results are shown in Figure 9.

Respondents that were interested in vehicle recognition in the case of theft were then questioned about their privacy concerns. As shown in the following figure, 44 percent of all interested respondents did have privacy concerns. More males (50 percent) than females (40 percent) had concerns, and 45 to 46 percent of the two groups of younger respondents had privacy concerns, while only 41 percent of the 30 to 34 years olds did. There was no difference in those with and without children.

Intelligent parking

Another transportation application is intelligent parking, an app that can send advance notification, updated in real time, of the location of empty parking spaces near a driver's destination. Fifty-nine percent of respondents were interested in this application. Again, there was a significant difference according to gender, as 65 percent of males found the app interesting, while only 55 percent of females did.

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The two youngest groups of respondents found this application more interesting than the oldest group, and respondents that have children in their household were only somewhat more interested than those without children. This data is shown in Figure 11.

Compared to some of the other applications, a smaller number of respondents had a privacy concern regarding this application. As shown in Figure 12, only 36.5 percent of interested respondents expressed concern. While 43 percent of males were concerned, only 31 percent of females were. Twenty-five to 29 year olds were the most concerned (40 percent), while fewer 18 to 24 year olds (37 percent) and 30 to 34 year olds (33 percent) were. There was a small difference between those with and without children, as 36 percent of those with no children were concerned, while only 33 percent of respondents with children in their household were concerned.

Real-time traffic updates

An additional transportation-related application presented in the survey was real-time traffic updates with "look-ahead" video capability broadcast to a smartphone or in-vehicle screen. As shown in Figure 13, 56 percent of survey respondents were interested in this application, with more interested males (62 percent) than females (52 percent). The 25 to 29 year olds were the most interested age group, with almost 60 percent expressing interest, while the other age groups were only somewhat lower at 54 to 55 percent. There was no significant difference between groups with and without children.

Forty-one percent of all interested respondents had privacy concerns regarding real-time traffic update applications, as shown in Figure 14. While only 36 percent of females has concerns, 48 percent of males were concerned. The 25 to 29 year olds were the most concerned age group (44 percent), while the other age groups were only somewhat lower at 39 and 40 percent. There was no significant difference between those respondents with and without children.

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Entertainment

Several new applications for entertainment will be possible with 5G service, with the first three applications discussed here designed to be used in a stadium or arena. A video delivery application could deliver video to an attendee's mobile device while they are seated in a stadium or arena. This video could include close-ups of the action on the field or court, for example.

Mobile video delivery in a Stadium/Arena

As Figure 15 illustrates, 44 percent of respondents found this type of application interesting, with significantly more males (55 percent) than females (37 percent) doing so. More of the youngest two groups of respondents (48 percent) found this interesting than the group of older respondents (38 percent). Also, respondents with children were much more likely than those without children to find interest in mobile video delivery at an event – 50 percent compared to 41 percent.

When compared to other 5G applications, a smaller number of interested respondents had privacy concerns with mobile video delivery at an event, as only 36 percent were concerned. Many more males than females were concerned (42 percent compared to 30 percent), while there was no significant difference between the age groups or those with or without children. These results are shown in Figures 15 and 16 in the Appendix.

Concessions delivery in a stadium/arena

Popcorn, drinks or other concessions can be delivered to an attendee while they are seated in a stadium or arena. Respondents were asked about their interest in using a mobile application to select from a range of food and beverages and have the concessions delivered right to their seat in a stadium or arena. More respondents were interested in concession delivery than mobile video delivery while at an event. The following figure illustrates that 50 percent of respondents were interested, including 59 percent of males and only 44 percent of females. The youngest respondents were the most likely to be interested in concessions delivery. Those respondents with children were somewhat more interested in this service than those without (52 percent versus 47 percent).

Similar to mobile video delivery in a stadium, when compared to other 5G applications a smaller number of interested respondents had privacy concerns with concession delivery at an event, as only 37 percent were concerned. Many more males than females were concerned (44 percent compared to 31 percent), while there was no significant difference between the age groups or those with or without children. These results are shown in Figure 18.

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Real-time betting or gambling in a stadium/arena

The third and final application designed for a stadium or arena provides real-time betting or gambling. This type of application, which could allow attendees to place bets on their personal mobile device during a game, was the least interesting of the three stadium applications to the survey respondents. As shown in Figure 19, only 36 percent of respondents were interested.

There was an extreme difference in results by gender: 49 percent of males were interested, but only 27 percent of females were. There was some difference by age, as only 33 percent of the 30 to 34 year olds were interested, but 37 to 38 percent of the younger respondents were. There was also a small difference in those with and without children.

Figure 20 shows that 40 percent of those interested in real-time gambling had privacy concerns, including 46 percent of males and 34 percent of females. The privacy concerns were somewhat differentiated by age, as 42 percent of 18 to 24 year olds were concerned, but only 37 percent of 30 to 34 year olds were. The results also show that there was no significant difference between those with and without children.

Mobile gaming with AR/VR

Two additional 5G entertainment applications provide gaming. The first, mobile gaming with augmented reality and virtual reality, allows mobile users to use their personal mobile device to play games in AR/VR while away from the home. As shown in Figure 21, almost half of respondents were interested in this application, with very significantly more males (61 percent) interested than females (41 percent). There was also a significant difference by age: 55 percent of 18 to 24 year olds were interested, 50 percent of 25 to 29 year olds, but only 42 percent of 30 to 34 year olds. Finally, 52 percent of respondents with children were interested in mobile gaming with AR/VR, while only 46 percent of those without children expressed interest.

Regarding mobile gaming (Figure 22), 38 percent of respondents expressed privacy concerns, including 47 percent of males and 31 percent of females. A somewhat higher percentage of the youngest respondents than the oldest respondents had privacy concerns – 40 percent versus 36 percent. When comparing those respondents with and without children, there was a similar difference – 40 percent of those with children versus 36 percent of those without.

Cloud-based gaming

The next gaming application presented in the survey was cloud-based gaming, such as Google Stadia or Microsoft's Project xCloud. Respondents' interest in this type of gaming application was less than their interest in mobile gaming with AR/VR (Figure 23). Forty percent of all respondents were interested in cloud-based gaming, including 52 percent of males and 32 percent of females, a significant difference by gender.

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There was also a significant difference in interest level by age groups: 45 percent of 18 to 24 year olds were interested, 40 percent of 25 to 29 year olds, but only 35 percent of 30 to 34 year olds. There was also significantly more interest among respondents with children (43 percent) than those without (36 percent).

Respondents expressed a little more concern about privacy with cloud-based gaming than with mobile gaming, with 43 percent of interested respondents in cloud-based gaming having concerns, as shown in Figure 24. Again, a higher percentage of males (51 percent) than females (36 percent) were concerned, but there was no significant difference among age groups or respondents with and without children.

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Personal/Public Safety

The last group of 5G applications provide functionality to improve the personal safety of users or improve the ability of public safety organizations to respond.

Child tracker using facial recognition

A child tracker application uses facial recognition to track a child. The application could notify the parent when the child has left school grounds, for example, and provide real-time information about the child's location. As shown in Figure 25, 53 percent of all respondents expressed interest in this type of application. There was less difference between genders than *iG*R noted in other applications: 55 percent of males and 52 percent of females were interested in the child tracker application. The older respondents expressed less interest in the child tracker application: only 49 percent of 30 to 34 year olds, compared to 55 or 56 percent of the two younger groups. Not surprisingly, a larger percentage of respondents with children in their household (65 percent) than those without children (43 percent) expressed interest in the child tracker app.

Overall 55 percent of interested respondents had privacy concerns regarding the child tracker application (Figure 26). More males than females (58 percent compared to 53 percent) expressed concern, but there was no significance difference between the three age groups or those respondents with and without children.

Pet tracker

A pet tracker application allows users to know where their pet is at all times and also uses image recognition to provide information in the event the pet leaves its home. Fifty-three percent of respondents were interested in this application (Figure 27), which is the same number as those interested in the child tracker app. More males (57 percent) than females (50 percent) were interested. There was also some difference between age groups, as 55 percent of 18 to 24 year olds, 53 percent of 25 to 29 year olds, and only 49 percent of 30 to 34 year olds expressed interest. However, there was very little difference between respondents with and without children.

Forty percent of those respondents who were interested in the pet tracker application expressed privacy concerns (Figure 28), including 46 percent of males and 35 percent of females. The oldest respondents were less concerned about privacy, but there was little difference between those with and without children.

On-demand medical

The next 5G application for a mobile device provides on-demand access to a doctor and remote medical diagnosis. Fifty-three percent of all respondents were

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interested in such a remote medical diagnosis app (Figure 29), including somewhat more males (57 percent) than females (51 percent). There was some difference in interest according to age: 25 to 29 year olds were the most interested (57 percent), followed by 53 percent of 18 to 24 year olds, and only 47 percent of the oldest respondents. Fifty-eight percent of survey respondents who have children in their household were interested in remote medical diagnosis, while only 50 percent of those without children expressed interest.

When looking at the privacy concerns of those interested in remote medical diagnosis (Figure 30), *iG*R found that 45 percent expressed concern, including 50 percent of males and 42 percent of females. There was no significant difference between age groups, but more respondents with children (47 percent) than those without children (42 percent) expressed concern.

Automatic tow truck and police notification of accident

A public safety 5G application could provide automatic tow truck and police notification in the event of a severe car accident, with the application also providing a video recording. Fifty-four percent of all respondents expressed interest in this type of public safety app (Figure 31), including 60 percent of males and 51 percent of females. There was some difference in interest according to age: 25 to 29 year olds were the most interested (58 percent), followed by 55 percent of 18 to 24 year olds, and only 49 percent of the oldest respondents. Sixty-one percent of survey respondents who have children in their household were interested in this application, which was significantly more than the 50 percent of respondents without children who expressed interest.

Of those interested respondents, 44 percent expressed a privacy concern with the automatic tow truck and police notification app (Figure 32). More males (50 percent) than females (40 percent) were concerned, and there was some difference according to age: 25 to 29 year olds were the most concerned (48 percent), followed by 44 percent of 18 to 24 year olds, and only 42 percent of the oldest respondents. However, there was little significant difference between the privacy concerns of those with and without children.

ER doctor access from ambulance

Another public safety 5G application could give an ER doctor access to a patient in an ambulance, in order to start the process of triage. Overall, 55 percent of survey respondents were interested in this type of application (Figure 33), with more males (59 percent) than females (52 percent) interested. There was no significant difference in interest among the three age groups, but there was a difference between those respondents with children and those without: 60 percent of those with children expressed interest, while only 52 percent of those without did so.

Figure 34 shows that 45 percent of interested respondents had privacy concerns regarding this medical/public safety application, including 51 percent of males and 40 percent of females. The youngest respondents had the lowest level of privacy

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concerns (only 41 percent of 18 to 24 year olds), while 50 percent of 25 to 29 year olds were concerned about their privacy.

Real-time information access for emergency services

The final public safety application presented to survey respondents was an app that would provide public safety employees in police, fire and ambulance access to real-time information in order to improve their ability to react to emergencies in the city. Sixty percent of all respondents expressed interest in this app (Figure 35), with no difference between males and females, very little difference between age groups, and little difference between respondents with and without children at home. Among all of the applications highlighted in this survey, this application showed the least amount of variance among demographic segments.

Among the interested respondents, 44 percent expressed privacy concerns (Figure 36), including 48 percent of males and 41 percent of females. There was no significant difference between the three age groups, but there was a slight difference between those with children (47 percent concerned) and those without children (43 percent concerned).

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Summary of Interest and Privacy Concerns for 5G Applications and Services

Interest

The previous section not only demonstrated the wide range of applications and services that can be enabled by 5G, but also quantifies the high levels of interest in these applications among 18 to 34 year olds, the future users of 5G. Obviously, more 5G apps and services are possible, but the goal here was to show the demand for the basic 'building blocks' that could be used to enable other services.

More than half of respondents expressed interest in all of the **transportation** apps. Sixty percent and 59 percent expressed interest in vehicle recognition apps to help in the event of a stolen car and intelligent parking, respectively. Real-time traffic updates with "look-ahead" video capability was interesting to almost as many (56 percent), while half of respondents were interested in parking lot license plate monitoring.

Several **entertainment** applications, including three to be used in a stadium or arena, were presented in the survey. Concessions order and delivery was interesting to half of respondents, mobile video delivery in a stadium or arena was interesting to 44 percent, and real-time betting in the arena was interesting to 36 percent. And 49 percent and 40 percent of respondents were interested in mobile gaming with AR/VR and cloud-based gaming, respectively.

With a more narrow/targeted market, the interest rate of these entertainment apps increases significantly. For example, 59 percent of males were interested in mobile concessions order and delivery, and 61 percent of males were interested in mobile gaming with AR/VR.

All of the **personal and public safety** applications were interesting to over half of respondents. Child and pet tracking applications, remote medical diagnosis applications, automatic tow truck and police notification applications, and apps that give ER doctors access to ambulances were interesting to 53 to 54 percent of respondents. An even higher number of respondents (60 percent) found applications that give public safety employees access to real-time information interesting.

Again, with a focused market, the interest levels rose higher still. For example, 65 percent of respondents with children were interested in the child tracker application, and over 60 percent of respondents with children were interested in the automatic tow truck and police notification applications, as well as apps that give ER doctors access to ambulances.

In general, the interest level in retail advertising applications was lower than that of transportation, entertainment or personal/public safety applications, with 39

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percent of respondents showing interest in facial recognition in physical retail stores for targeted advertising and 36 percent expressing interest in user recognition in online retail.

Privacy Concerns

The results of *iG*R's survey also show a somewhat high level of concern about privacy among potential 5G users.

Not surprisingly, the highest level of concern was expressed for applications that 'recognize' users. Over half of interested respondents expressed concern for the following three applications:

- Child tracker – 55 percent concern rate
- Facial recognition and targeted ads in physical retail stores – 49 percent concern rate
- User recognition for online ads – 49 percent concern rate.

Public safety applications that earned high interest levels among respondents still caused concern about privacy among almost half of respondents. For example:

- Remote Medical Diagnosis – 45 percent concern rate
- Apps that give ER doctors access to an ambulance for triage – 45 percent concern rate
- Police and tow truck notification in the event of a serious car accident – 44 percent concern rate
- Vehicle recognition in the event of a stolen vehicle – 44 percent concern rate.

Even applications that seemingly would not create concern about privacy caused concern in more than one third of respondents. The following three applications had the lowest levels of concern:

- Mobile video delivery in an arena or stadium – 36 percent concern rate
- Intelligent parking to find empty spaces – 37 percent concern rate
- Concessions delivery in an arena or stadium – 37 percent concern rate.

This concern over privacy among interested 5G users demonstrates the need for a secure solution combined with the enabling 5G hardware and software. Simply adding security as an afterthought will not suffice – consumers must feel secure when using these apps and services. For example, facial recognition imagery should be processed at the edge, as close to the camera as possible – and once actioned, deleted.

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Role of ADLINK in supporting 5G Services

Headquartered in Taiwan, ADLINK has operations in the United States, UK, Singapore, Beijing, Shanghai, Shenzhen, Japan, Korea and Germany. ADLINK is proud to be associated with many major technology leaders and Fortune 500 companies. By leveraging more than 20 years of expertise in developing highly reliable and available embedded computing systems, ADLINK is a premier supplier of extensive, cost-effective COTS, as well as fast time-to-market ODM solutions to worldwide tier-one TEMs and network solution providers. ADLINK has been an active contributor to leading industry consortia including the Open Compute Project (OCP), the Open Data Center Committee (ODCC), and the Telecom Infra Project (TIP). ADLINK's strategic global presence benefits customers with increased responsiveness, short delivery lead-time and ease of doing business. ADLINK ensures best practices in product obsolescence and lifecycle management by leveraging its long-standing strategic partnerships with major processor and software vendors.

Devoted to driving innovation by leveraging its next-generation Open Compute Carrier-grade Edge Reference Architecture (OCCERA), ADLINK has a goal to effect positive change in industry by connecting people, places and assets with artificial intelligence (AI) and Internet of Things (IoT) through the delivery of leading edge, robust and reliable hardware and software solutions that directly address mission-critical business and technology challenges.

The company offers a range of products to meet the needs of mobile network operators and enterprises as they deploy 5G, edge computing and AI solutions to support the applications and services covered in this paper.

Network Appliances Enable Next-gen Networking Applications

With the development and popularization of cloud computing technologies, traditional network security providers are repositioning and moving their development efforts from network security solutions that can only handle single-point security issues to a new generation of network security solutions that are effective in big data and cloud computing environments. Information and communications technology (ICT) equipment providers in the network security industry need network security servers that have massive deep packet inspection (DPI) parsing power, full support for network functions virtualization (NFV) and software defined networks (SDN), and a powerful big data processing engine. This equipment must also support dynamic capacity expansion and scalable I/O extension in order to adapt to a more complicated cloud environment.

ADLINK meets the network security requirements of e-businesses, enterprises, and service providers with its advanced network appliances that allow security solution providers to integrate next generation firewall (NGFW), intrusion detection and intrusion prevention system (IDS/IPS), distributed denial of service (DDoS), deep

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packet inspection (DPI), unified threat management (UTM), virtual private network (VPN), software-defined networking in a wide area network (SD-WAN) and universal customer premises equipment (uCPE) with industry leading performance, scalability, serviceability and manageability, all in one comprehensive security solution.

Built on the OCCERA, ADLINK's CSA provides a series of high performance, carrier-grade COTS network appliances, enabling system integrators to develop next-generation networking applications that deliver uninterrupted enterprise network services and fend off increasingly challenging cyber-attacks, through superior flexibility, modularity, scalability and more importantly, the highest processing and I/O density in the market. With the highly modular network interfaces, switches, and overall computing capacity integrated in one platform, the CSA is also accompanied by the PacketManager, a software package from ADLINK, to include control plane configuration tools and data plane processing acceleration capabilities. The CSA provides increased packet processing speed and offers unmatched configurability to enable cross-business product deployment and easy integration to other high-end network security markets. Featuring high throughput capacity and I/O density, parallel computing and computing density, carrier-grade high availability, and support for standardized API management, ADLINK's application-ready CSA series meets all of the stringent requirements of today's network applications, and therefore can significantly enhance customers' competitive advantage by allowing them to focus their development efforts on differentiating end applications. The CSA has been deployed globally by leading system integrators and service providers in a variety of high-profile use cases.

For more information about ADLINK's CSA network appliance, please visit the product webpage at https://www.adlinktech.com/en/Network_Security_Appliance.aspx

MEC Edge Servers Accelerate 5G Network Transformation

Multi-access Edge Computing (MEC) is an edge computing architecture standard created by the European Telecommunications Standards Institute (ETSI). Essentially, MEC is an evolution of cloud computing, moving data processing from centralized data centers out to the network edge and closer to application end users. In the era of 5G, having a clear edge computing implementation strategy largely determines if telecommunication operators can succeed in tapping into emerging service opportunities and winning over their competition.

As 5G deployments are accelerating worldwide, MEC architecture is also evolving quickly to keep up with the expansion of 5G networks. By bringing computing and intelligence closer to where data is generated and analyzed, as well as where real-time decisions are made, MEC is essential in enabling telecommunication operators to deliver on their 5G promises by significantly reducing latency, increasing connection speed, enhancing network security, and improving quality of service to end users. With the integration of MEC to effectively distribute networking demands, 5G's tremendously improved capabilities can handle an exponentially increasing number of connected devices and enable a wide range of latency and bandwidth dependent, cross-industry applications including autonomous vehicles,

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connected cars, virtual reality, augmented reality, smart city, smart transportation and smart manufacturing.

ADLINK is committed to developing industry-leading Edge Computing platforms to help customers accelerate the transformation of communications network architectures in the era of 5G. ADLINK's 1U/2U MEC servers MECS-6110 and MECS-7210, two new additions to its communication and networking product portfolio, are specifically designed to enable customers to explore new business models and service opportunities through new applications. Powered by dual Intel's advanced Xeon Scalable or Xeon-D processors, the two MEC servers are among the first platforms to fully comply with Open Telecom IT Infrastructure (OTII) defined by Open Data Center Committee (ODCC), making them a cost-effective solution for deployment in most existing infrastructure with the compact design and extended operating temperature. The two servers are both designed with dual full-height full-length (FHFL) PCIe expansion slots reserved for access to accelerated computing hardware such as GPU and FPGA. In one use case, a customer in the manufacturing industry deployed the MECS-7210 into the low-latency LTE/5G private network of its smart factory to effectively identify defective products, and improve operation efficiency through a GPU-based, AI-enabled application.

ADLINK's MEC servers enable solution providers to bring computing and intelligence closer to end users to deliver on 5G promises by significantly reducing latency, increasing connection speed, enhancing network security and improving quality of service. Working together on advanced, open architecture business initiatives with its broad range of strategic ecosystem partners, ADLINK is well positioned to facilitate the 5G network transformation and help service providers capitalize on enormous edge computing-enabled service opportunities with its leading MEC technologies and solutions.

For more information about ADLINK's MEC servers, please visit the product webpage at https://www.adlinktech.com/en/Edge_and_AI_Server.aspx

GPU-based Solutions Drive AI-enabled Edge Applications

Artificial Intelligence (AI) has the ability to innovate and advance conventional practices and business operations. To bring AI to the edge, ADLINK takes a GPU-enhanced heterogeneous approach and offers a comprehensive solution portfolio of machine learning/deep learning (ML/DL) platforms and servers including acceleration engines, inference platforms, and training servers to infuse the power of AI into a wide array of applications such as smart manufacturing, smart city, logistics and warehousing, telecommunications and networking and more. Levering the performance of 5G, GPU-based MEC solutions can effectively harness the power of AI, ML/DL and IoT technologies to open up enormous opportunities for service providers.

With many years of leadership across embedded computing markets, ADLINK deepened its long-term commitment to GPU platforms in 2018 by becoming an NVIDIA Quadro Embedded Partner for embedded graphics, HPC, and DL solutions. While ADLINK is one of 23 NVIDIA OEM Preferred Partners worldwide, only four of

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these (including ADLINK) have obtained NVIDIA's permission to create chip-down Quadro GPU solutions for ruggedized embedded markets. Going further still, ADLINK is one of only nine NVIDIA Jetson Preferred Partners. This rare degree of collaboration and commitment provides ADLINK with the highest levels of technical support from NVIDIA to help meet the demanding design, production, and product lifecycle requirements of the embedded market.

For more information about ADLINK's GPU-based solution, please visit the product webpage at https://www.adlinktech.com/en/gpu-solutions.aspx

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About *iG*R

*iG*R is a market strategy consultancy focused on the wireless and mobile communications industry. Founded by Iain Gillott, one of the wireless industry's leading analysts, we research and analyze the impact new wireless and mobile technologies will have on industries, the competitive landscape and on a company's strategic business plan.

A more complete profile of the company can be found at http://www.IGR -inc.com/.

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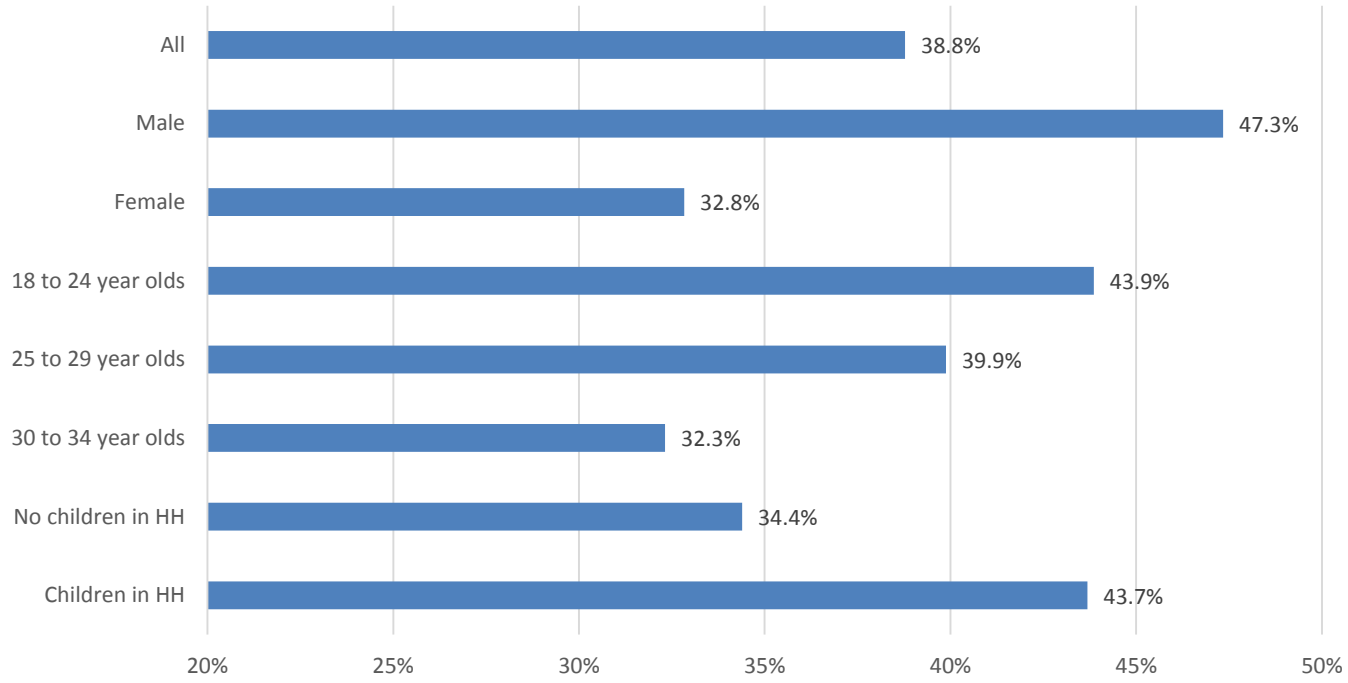
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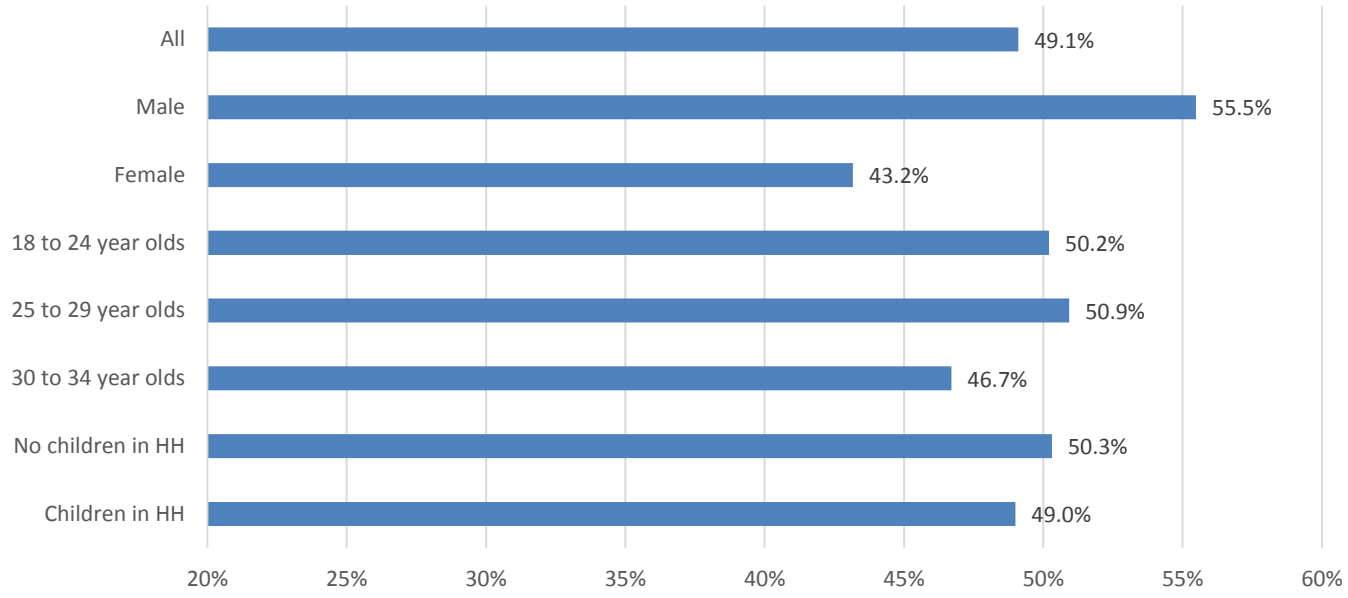
Appendix: Detail charts

Figure 3: Facial Recognition in Retail



Source: *iGR*, 2019

Figure 4: Facial Recognition in Retail – Privacy Concern

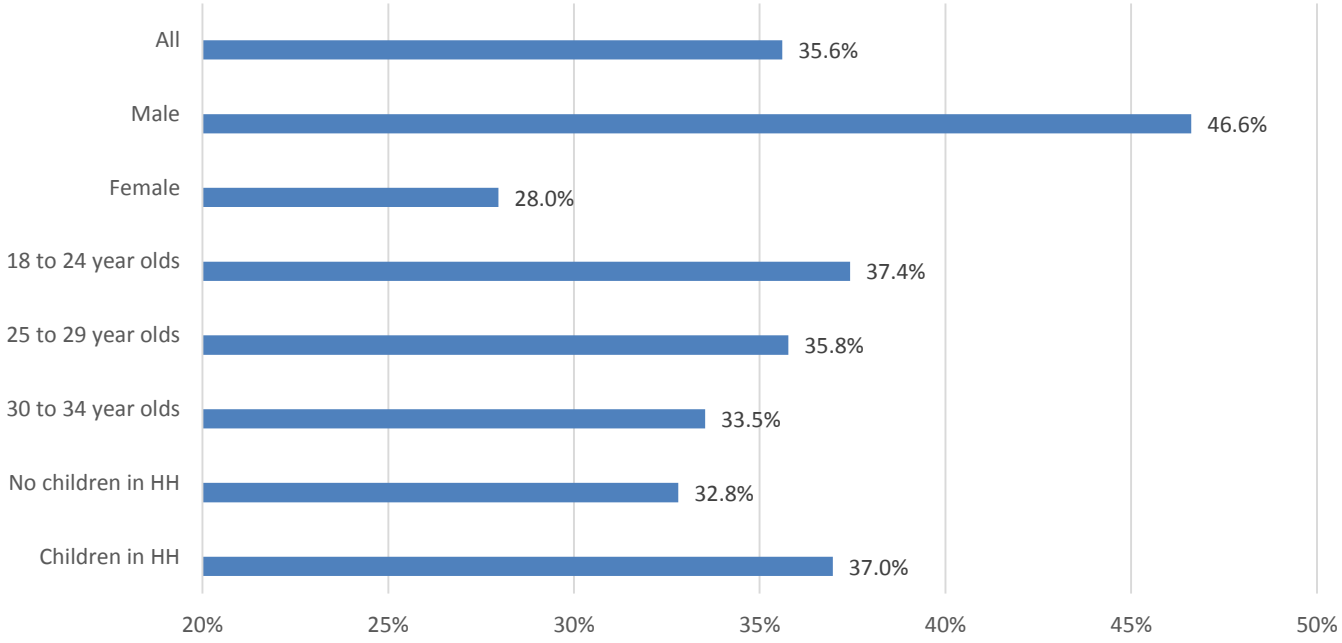


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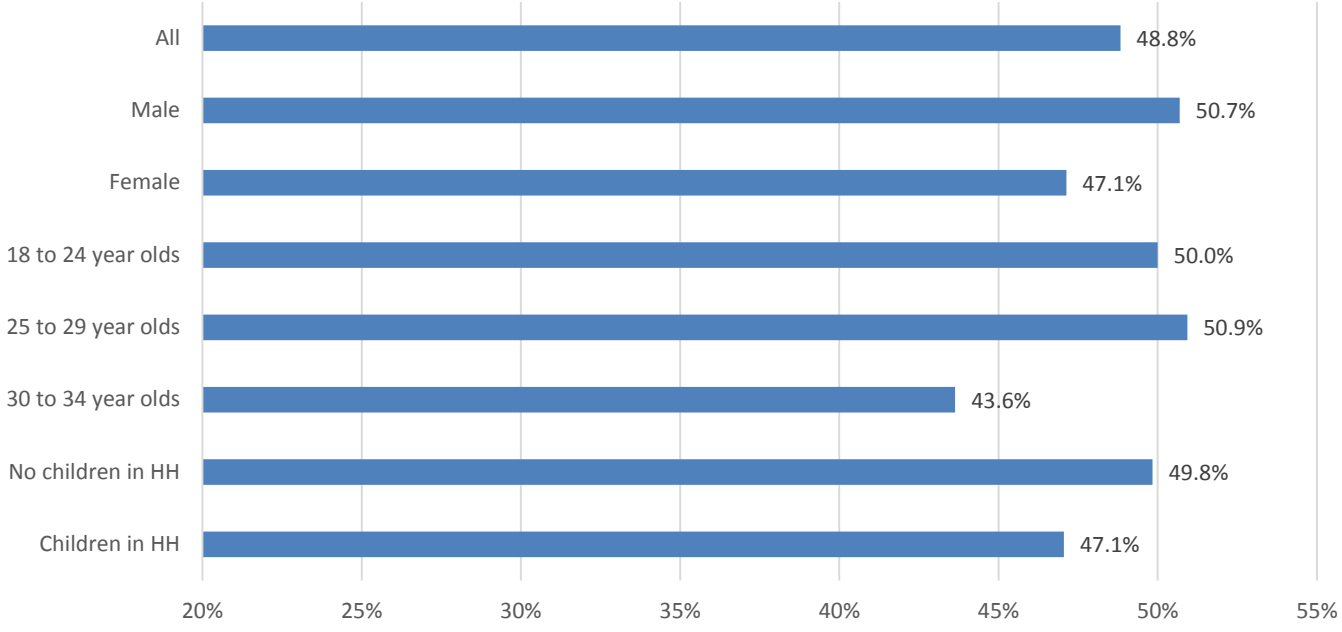
Source: *iG*R, 2019

Figure 5: User Recognition for Advertising in Online Retail



Source: *iG*R, 2019

Figure 6: User Recognition for Advertising in Online Retail – Privacy Concern

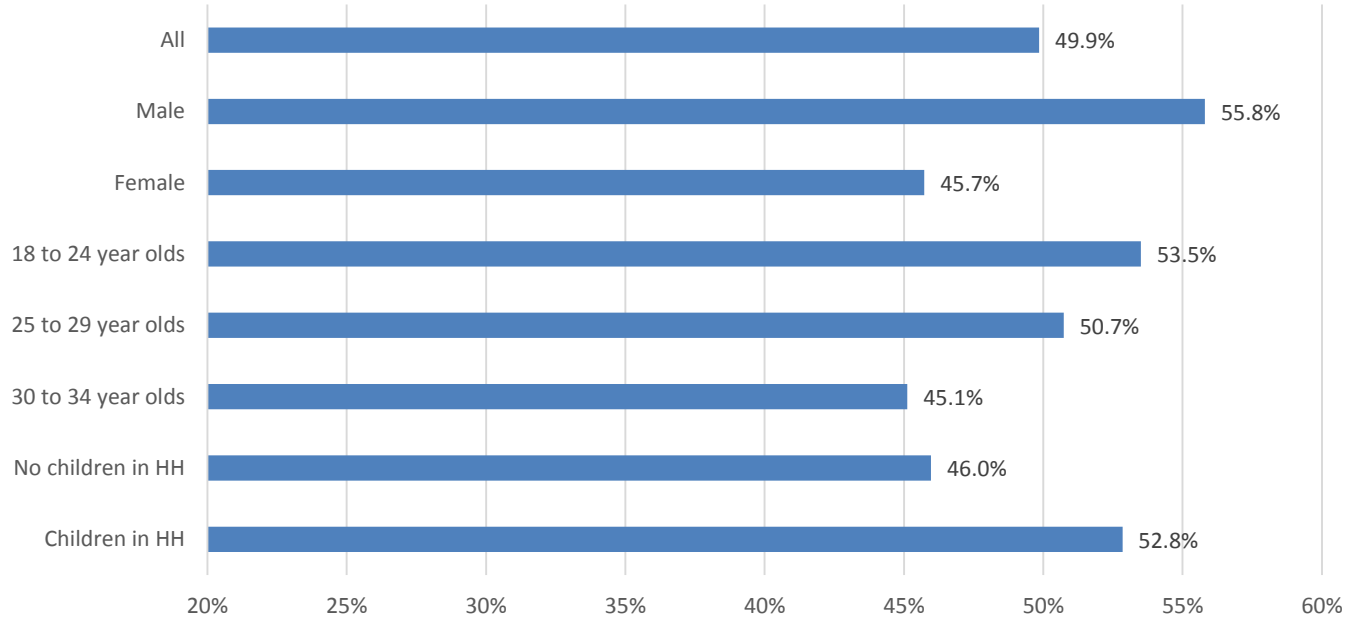


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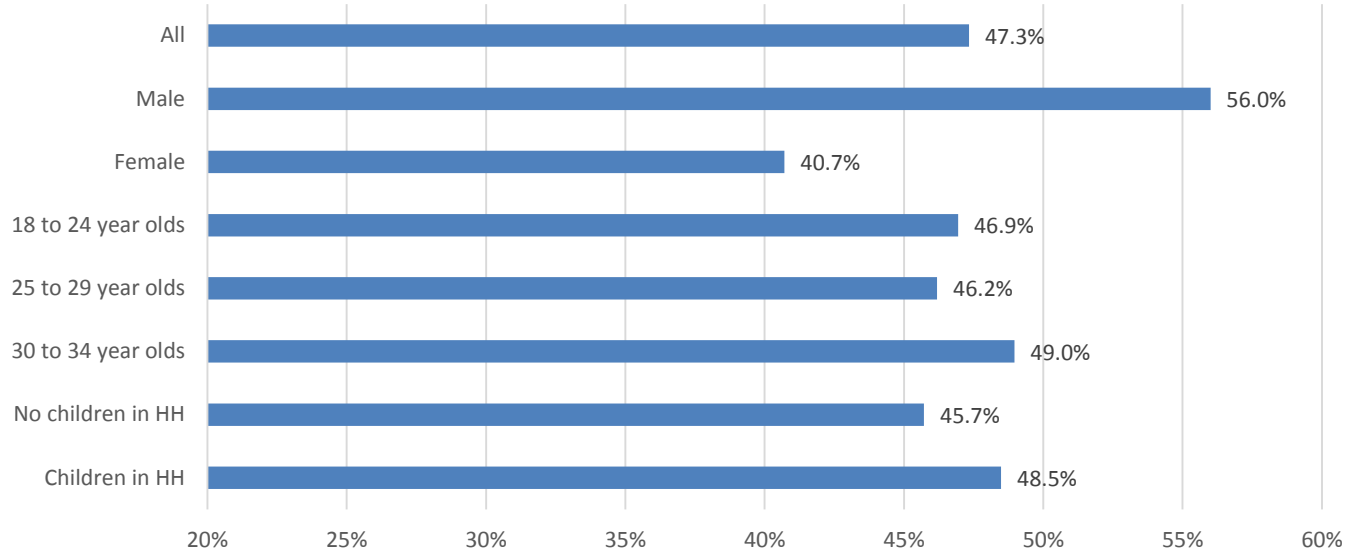
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Figure 7: Parking Lot License Plate Monitoring



Source: *iGR*, 2019

Figure 8: Parking Lot License Plate Monitoring – Privacy Concern

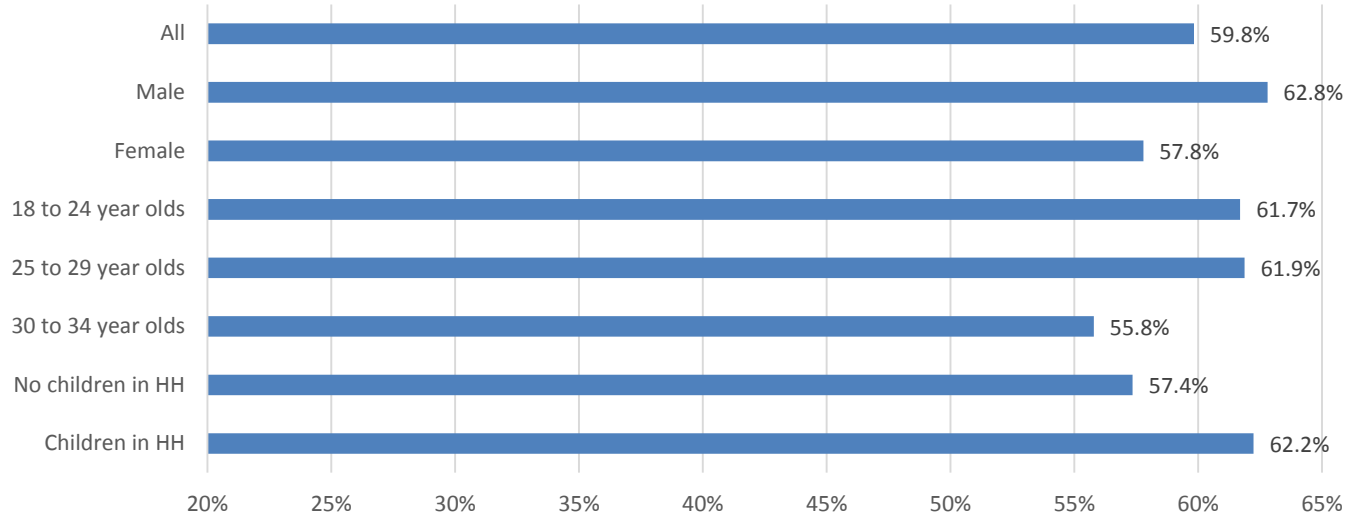


Source: *iGR*, 2019

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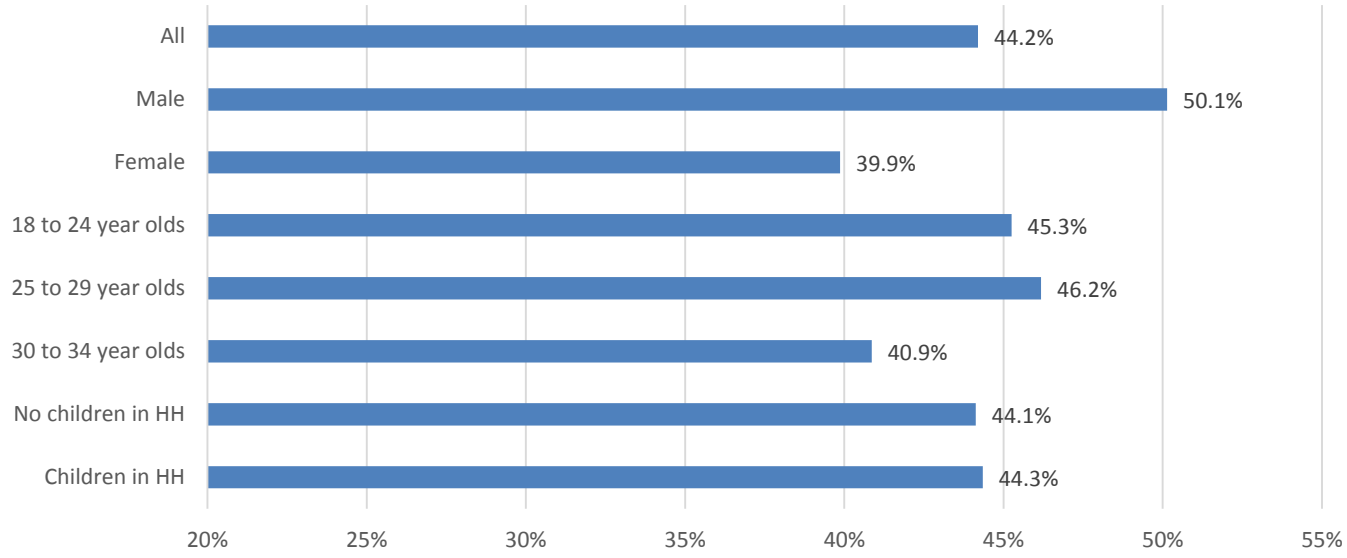
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Figure 9: Stolen Vehicle Recognition



Source: *iG*R, 2019

Figure 10: Stolen Vehicle Recognition – Privacy Concern

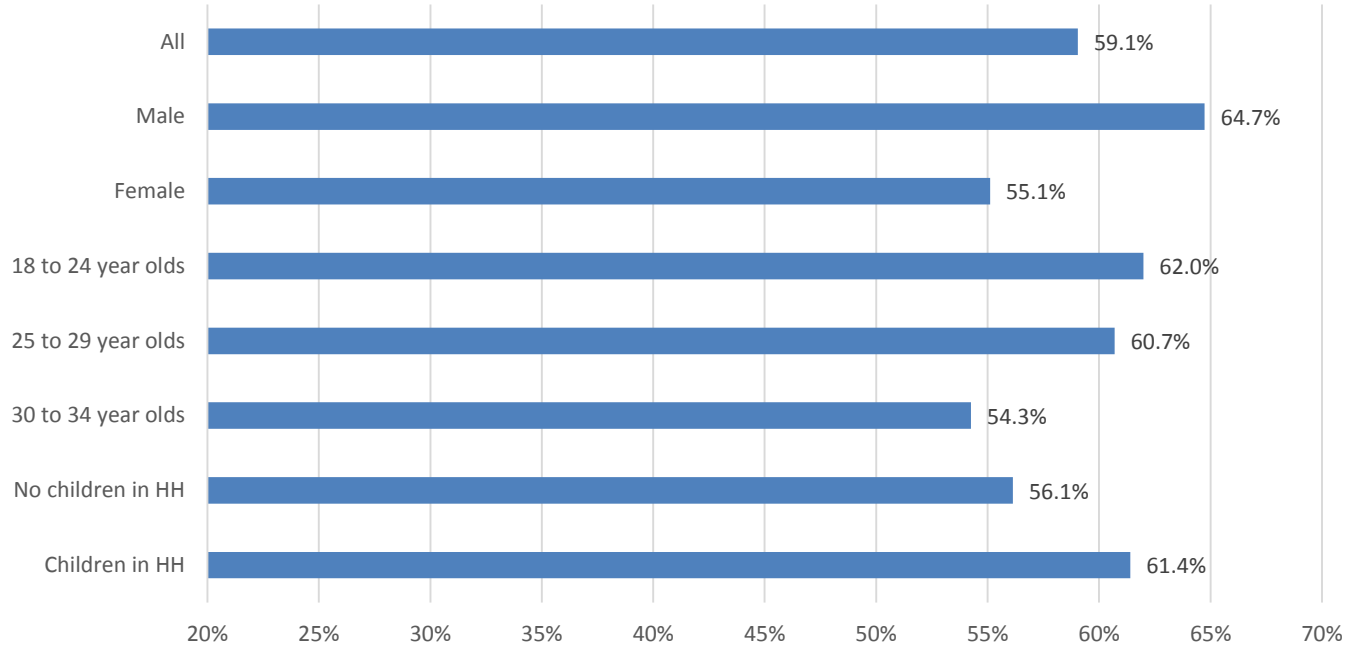


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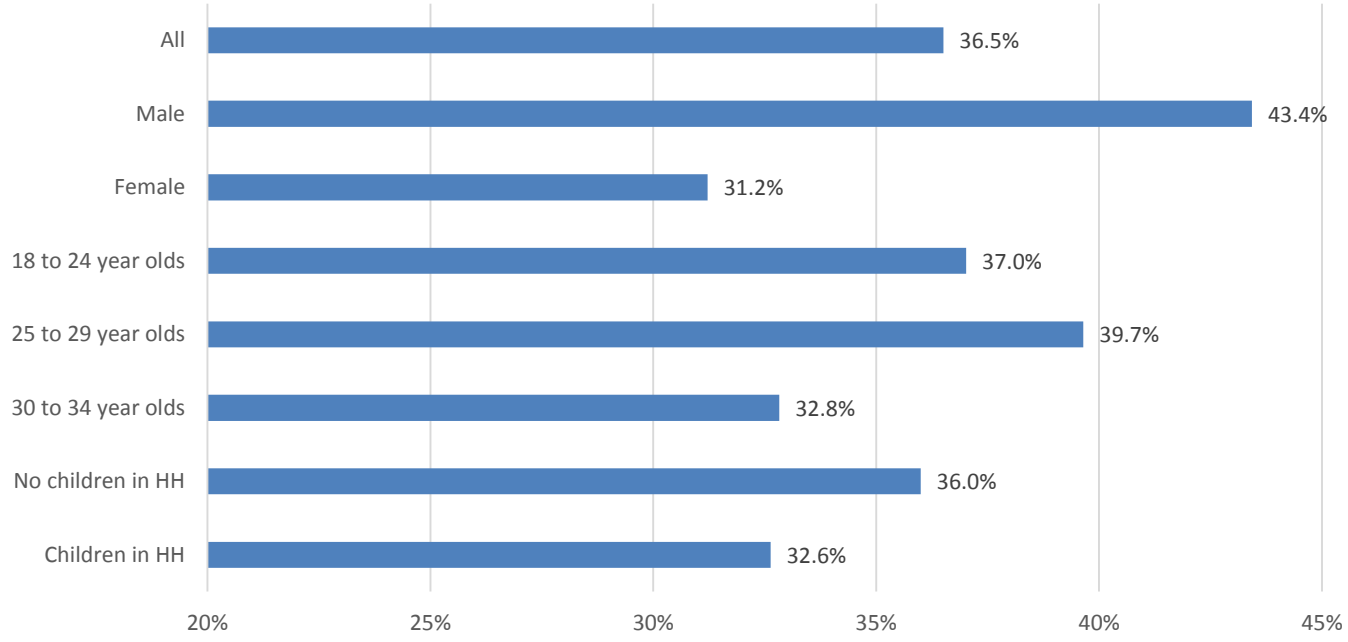
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Figure 11: Intelligent Parking



Source: *iGR*, 2019

Figure 12: Intelligent Parking – Privacy Concern

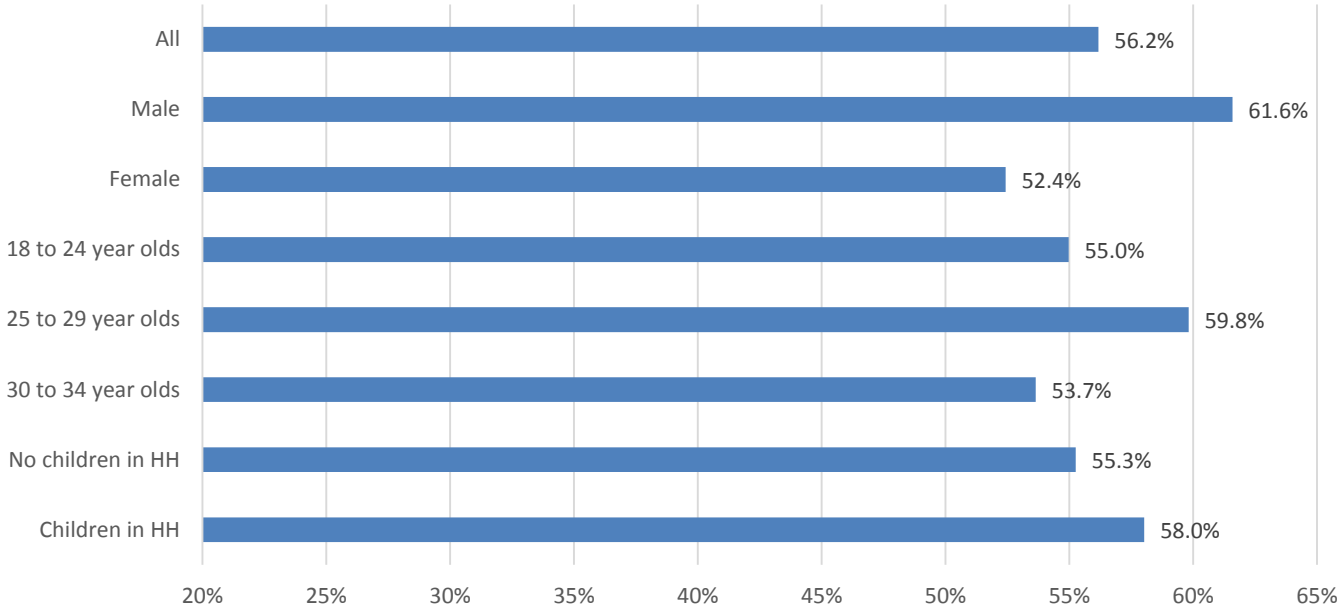


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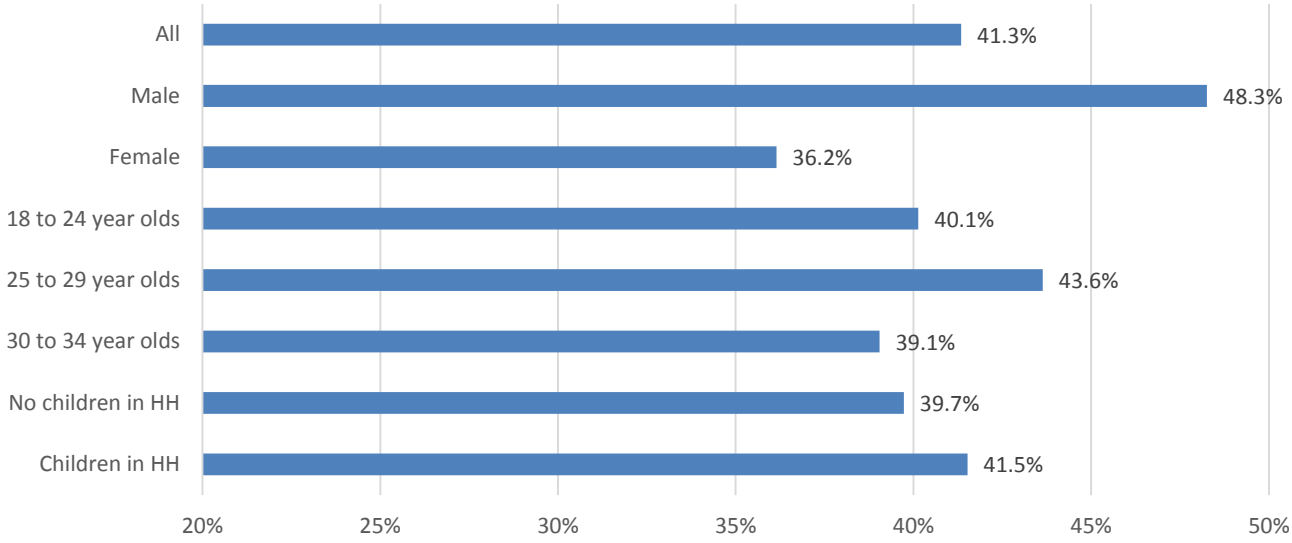
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Figure 13: Real-time Traffic Updates



Source: *iGR*, 2019

Figure 14: Real-time Traffic Updates – Privacy Concern

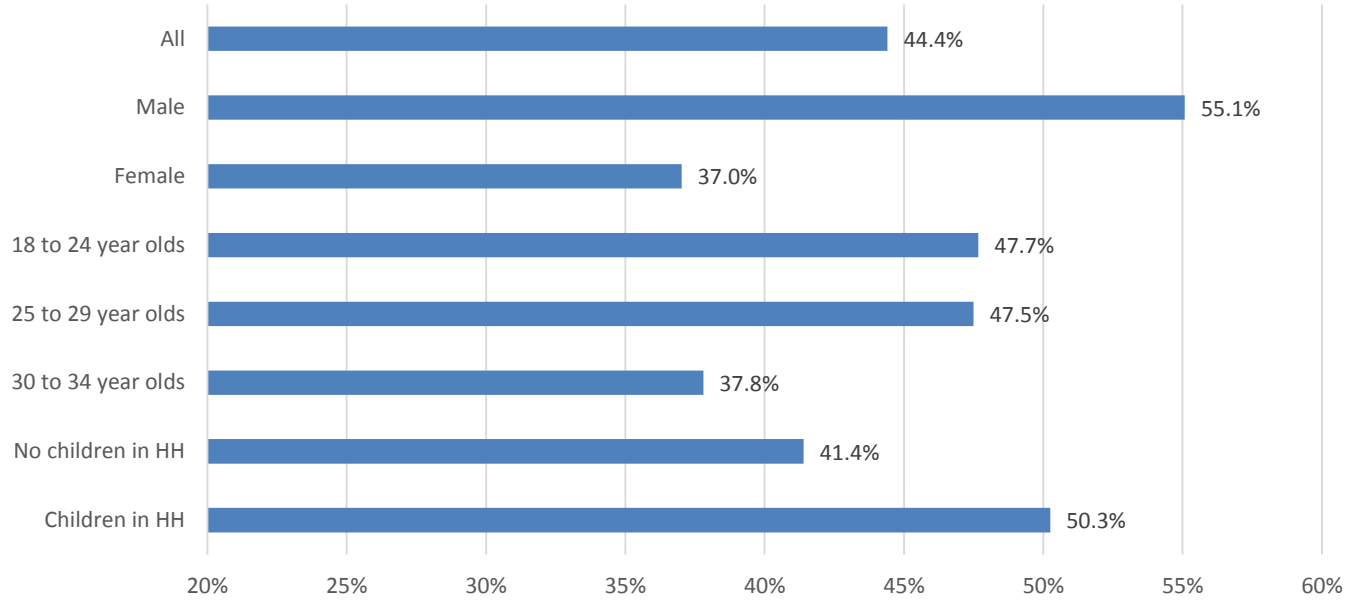


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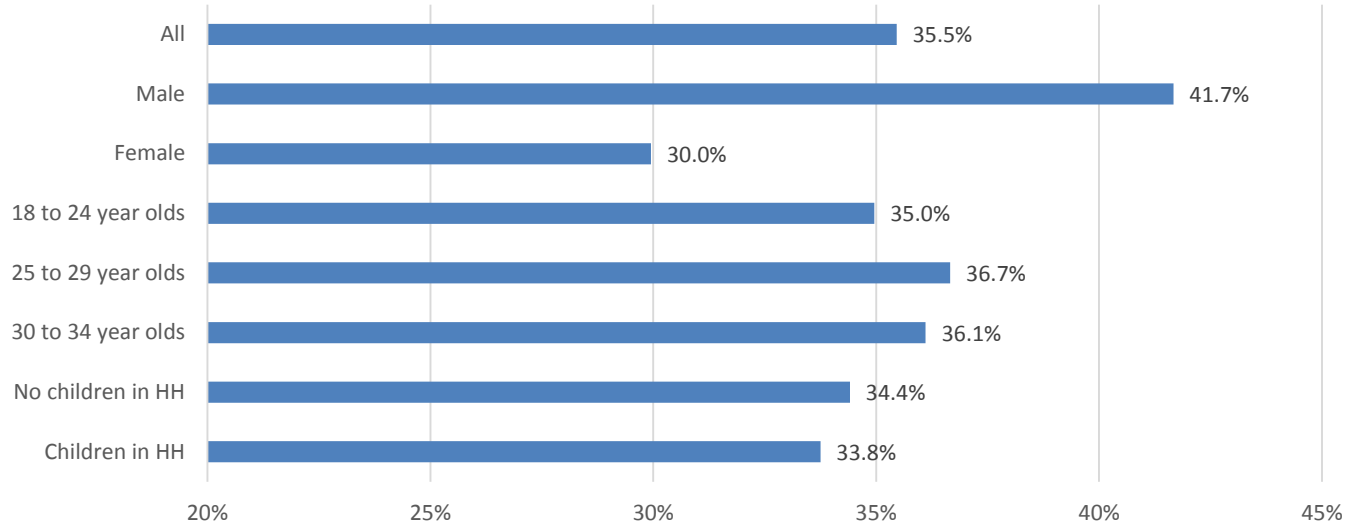
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Figure 15: Mobile Video Delivery in a Stadium/Arena



Source: *iGR*, 2019

Figure 16: Mobile Video Delivery in a Stadium/Arena – Privacy Concern

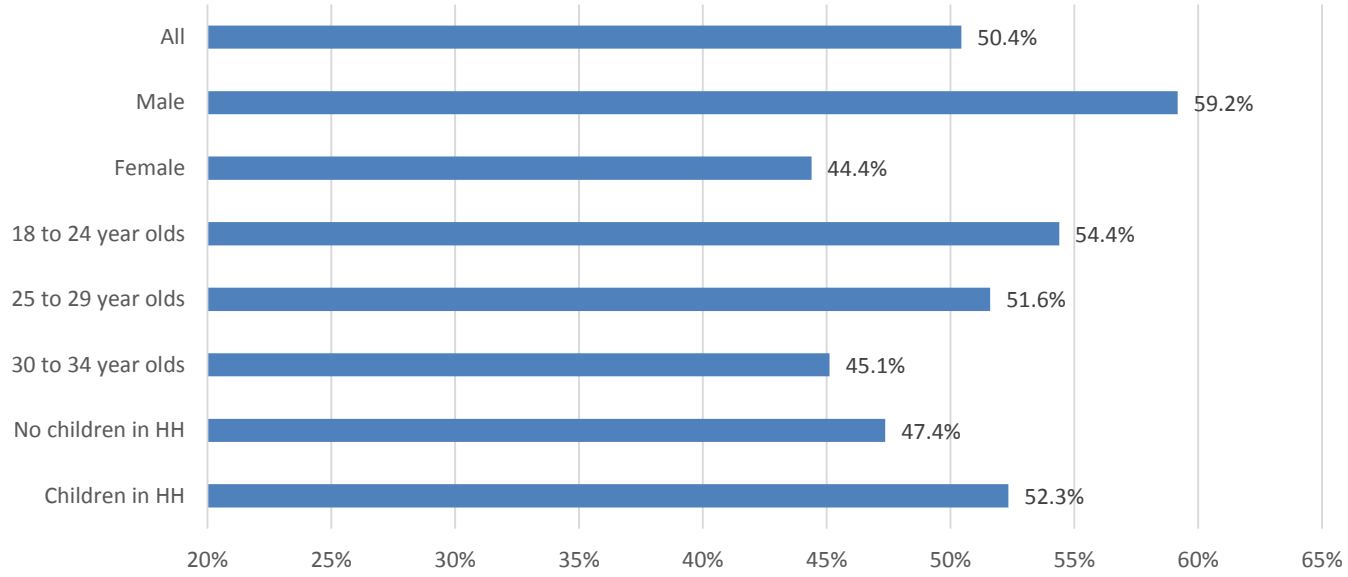


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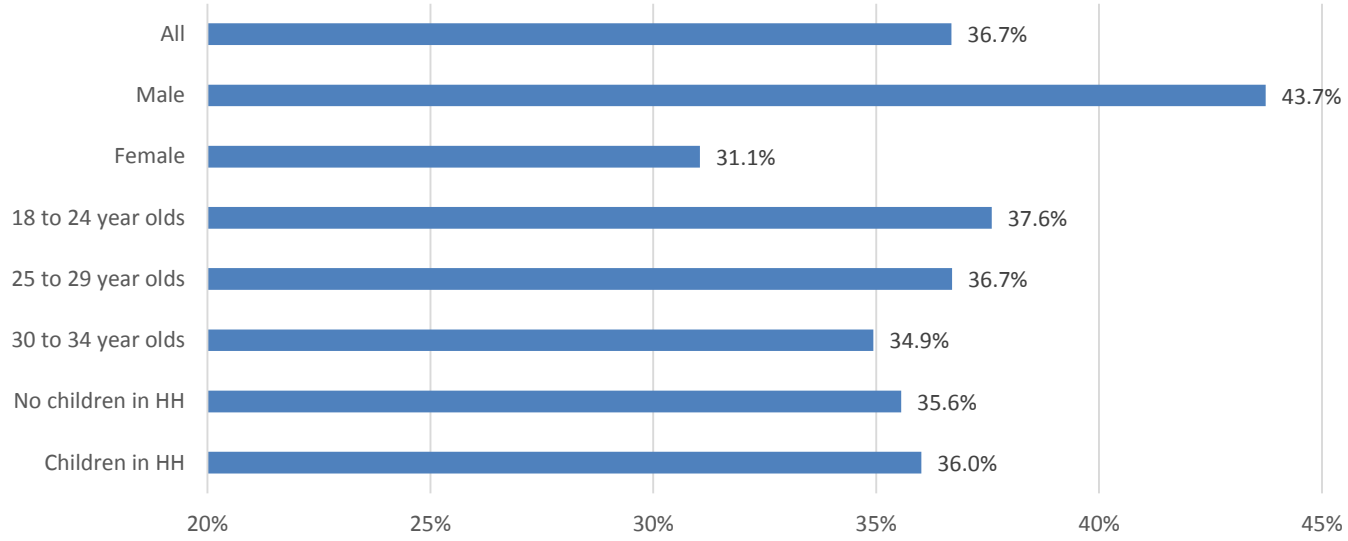
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Figure 17: Concessions Delivery in a Stadium/Arena



Source: *iGR*, 2019

Figure 18: Concessions Delivery in a Stadium/Arena – Privacy Concern

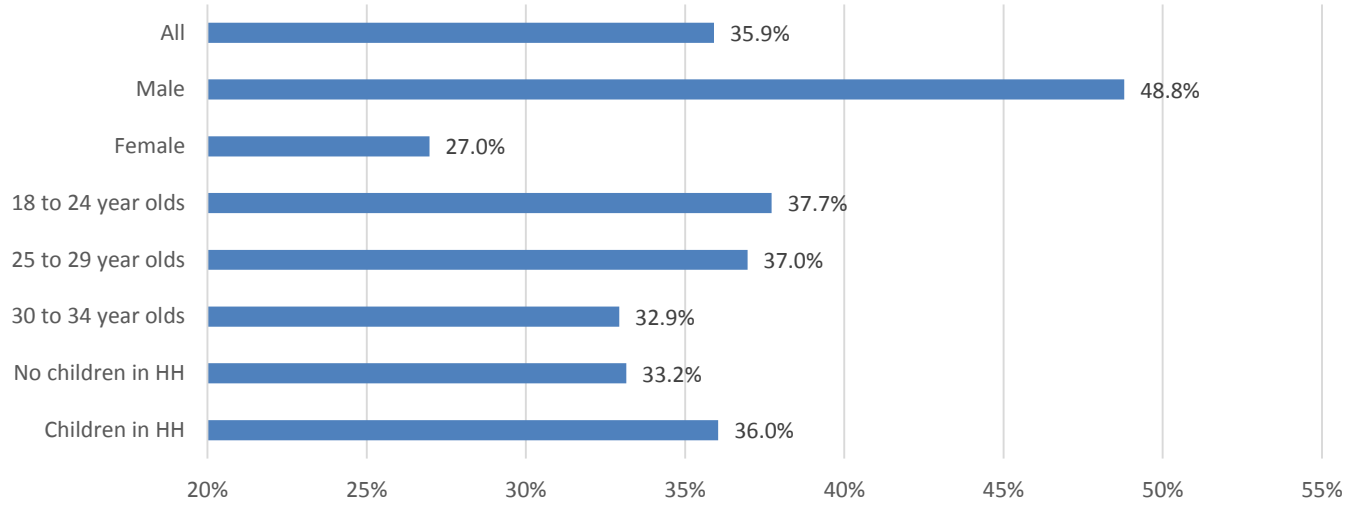


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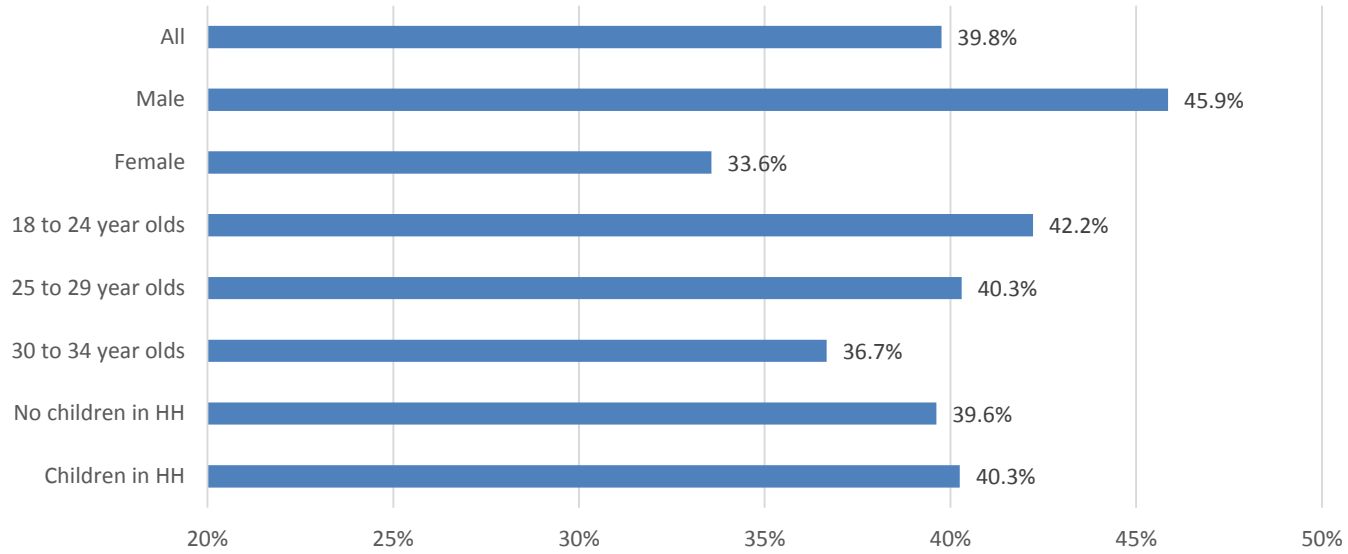
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Figure 19: Real-time Mobile Betting in a Stadium/Arena



Source: *iG*R, 2019

Figure 20: Real-time Mobile Betting in a Stadium/Arena – Privacy Concern

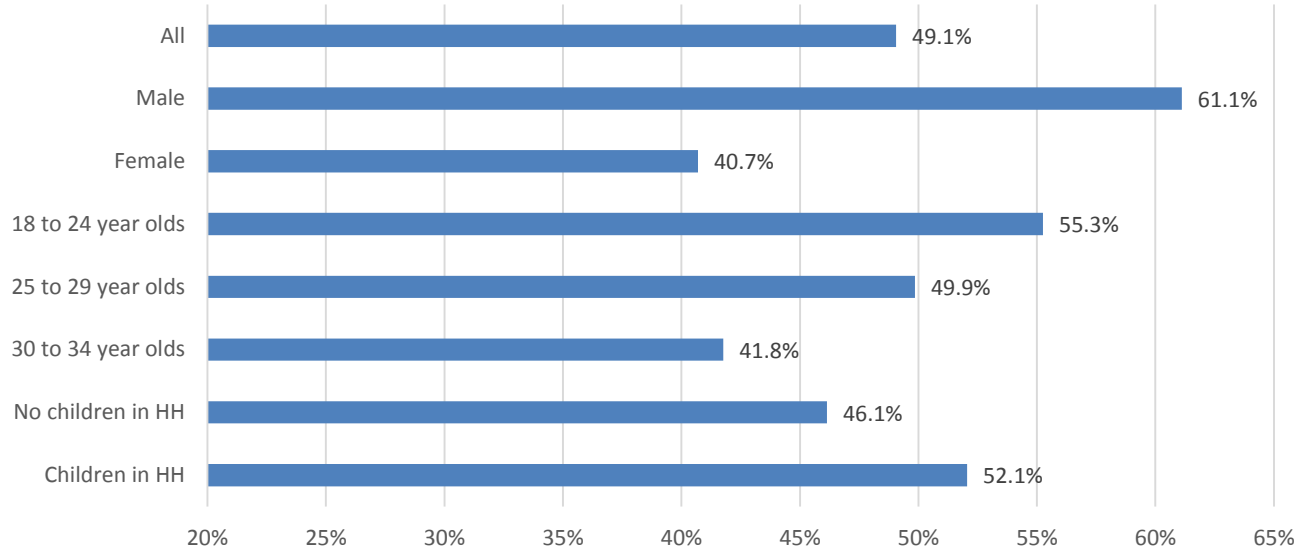


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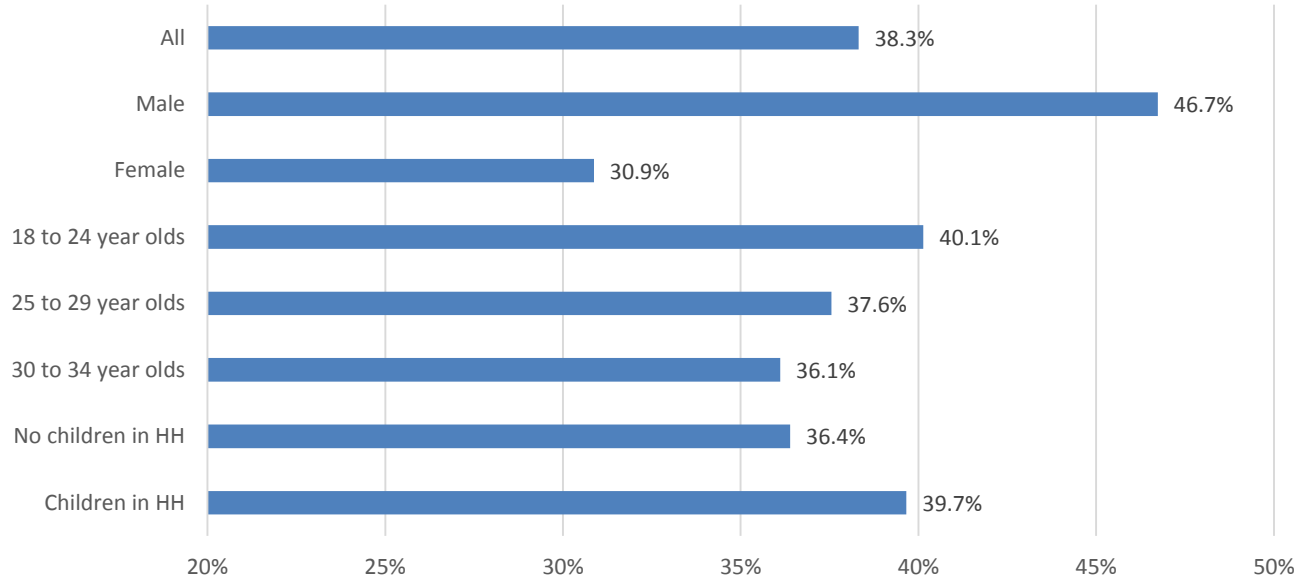
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Figure 21: Mobile Gaming with AR/VR



Source: *iGR*, 2019

Figure 22: Mobile Gaming with AR/VR – Privacy Concern

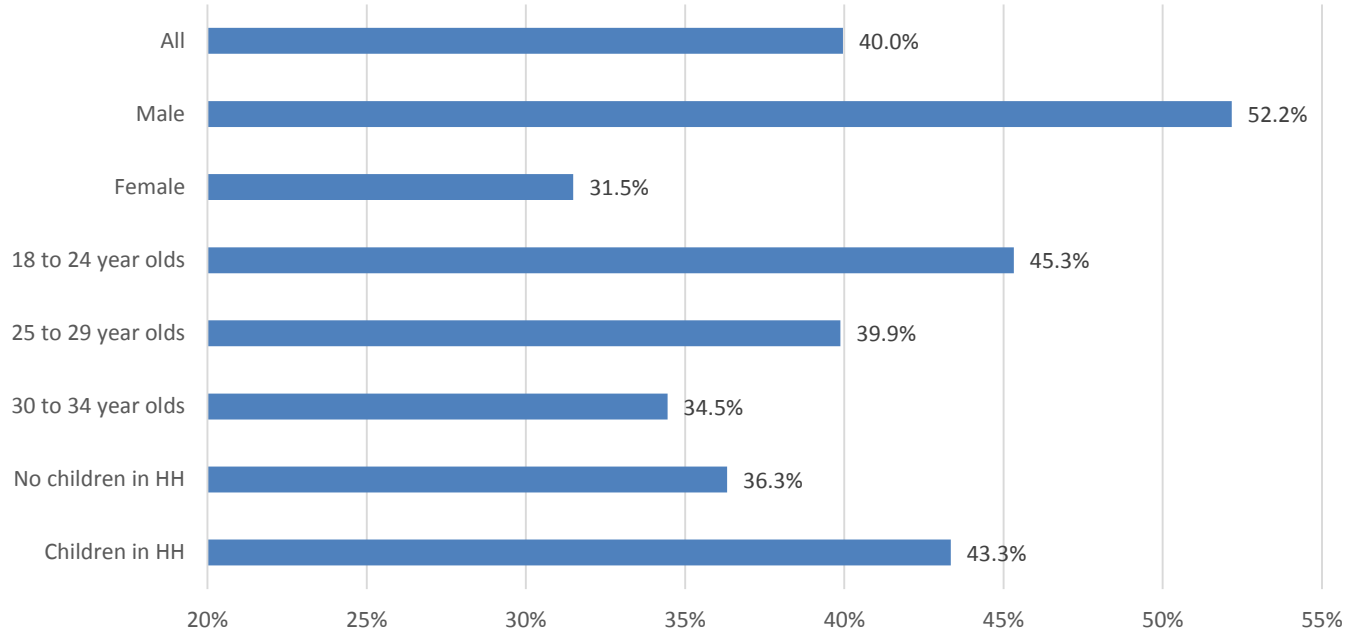


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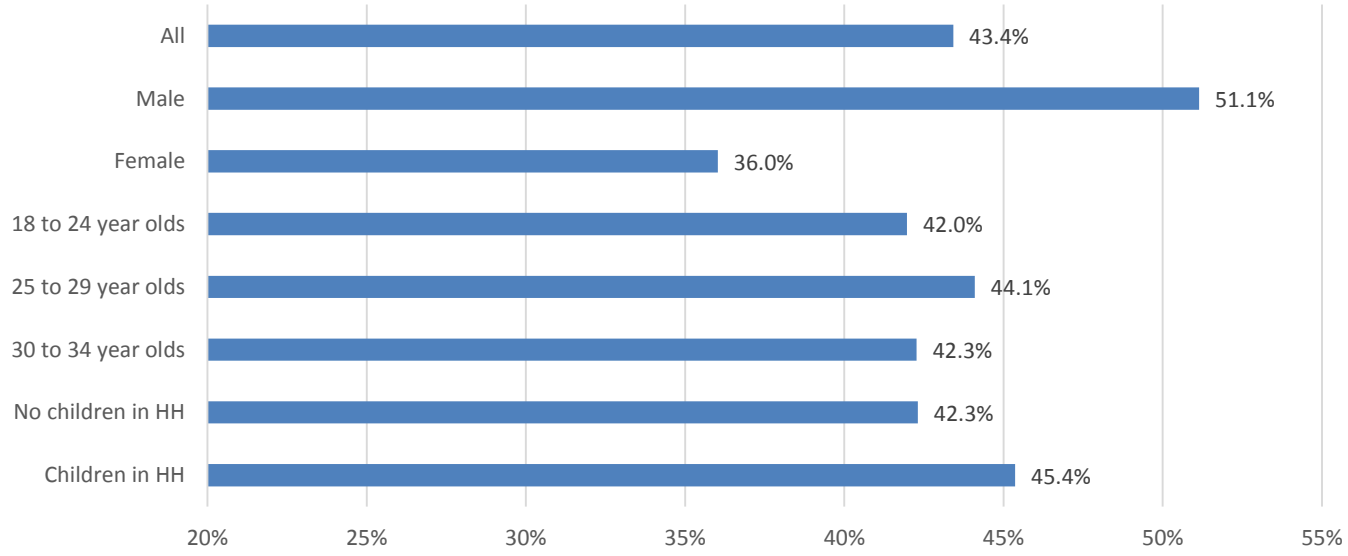
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Figure 23: Cloud-based Gaming



Source: *iGR*, 2019

Figure 24: Cloud-based Gaming – Privacy Concern

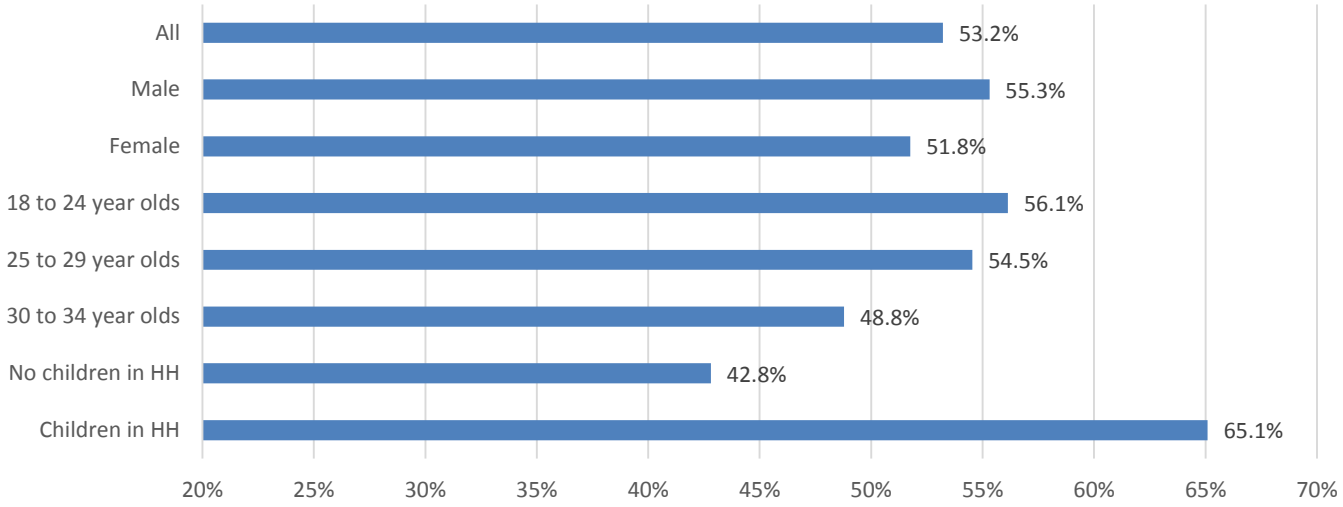


Source: *iGR*, 2019

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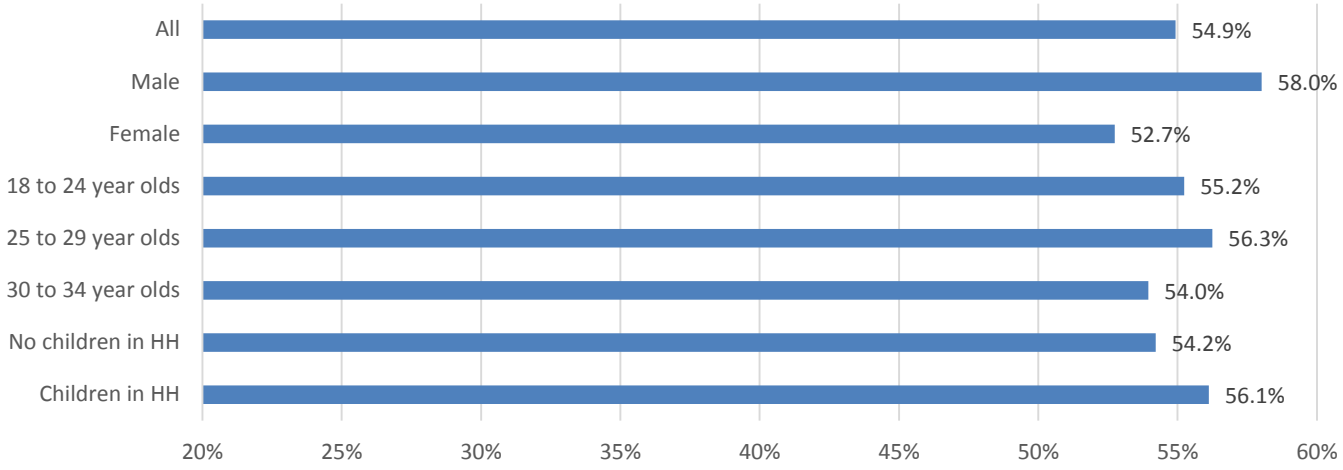
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Figure 25: Child Tracker



Source: *iG*R, 2019

Figure 26: Child Tracker – Privacy Concern

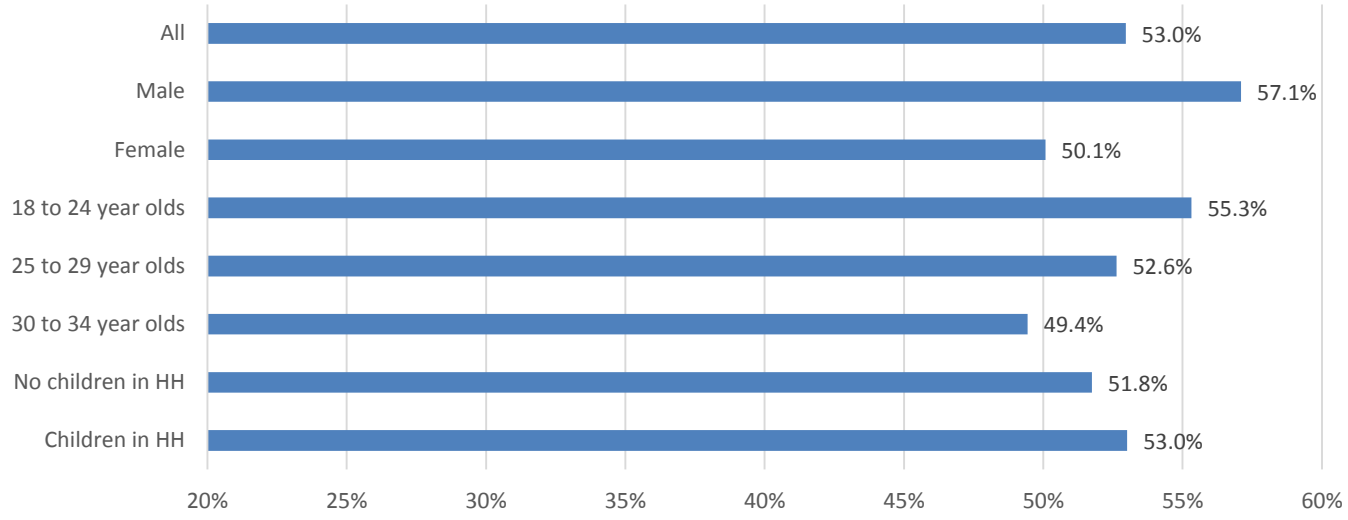


Source: *iG*R, 2019

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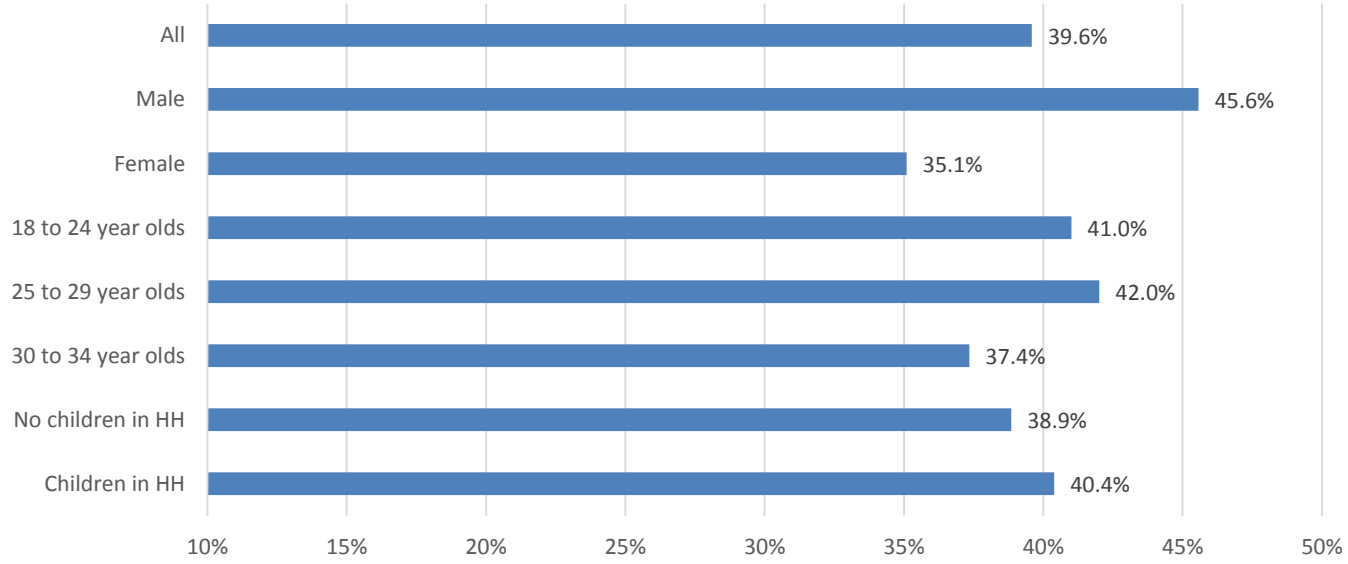
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Figure 27: Pet Tracker



Source: *iG*R, 2019

Figure 28: Pet Tracker – Privacy Concern

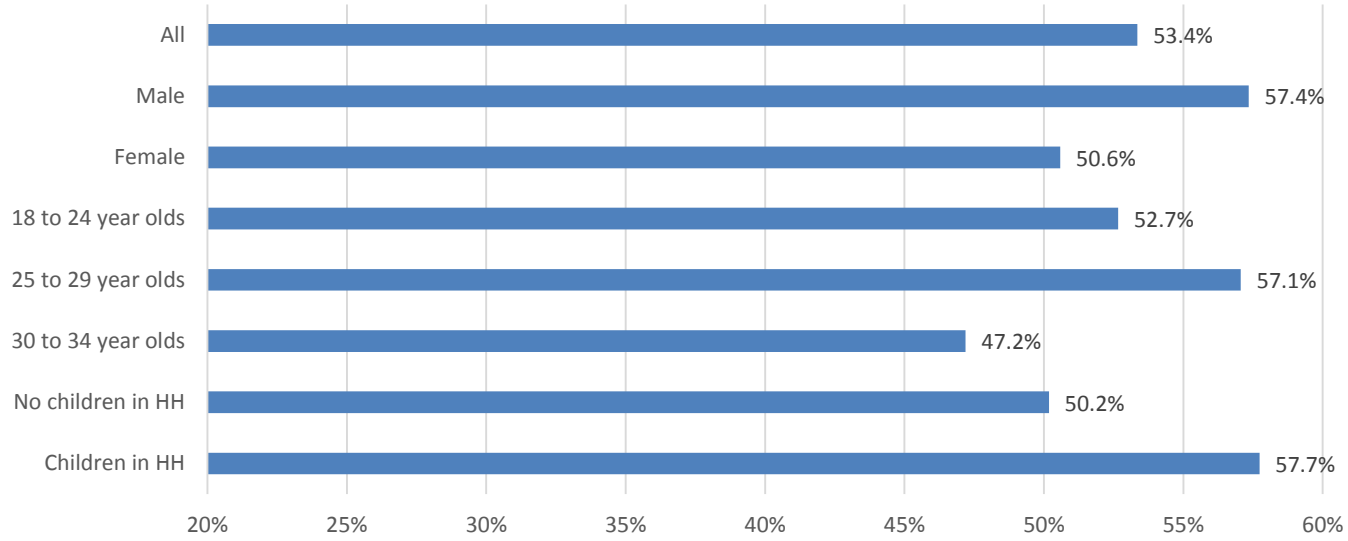


Source: *iG*R, 2019

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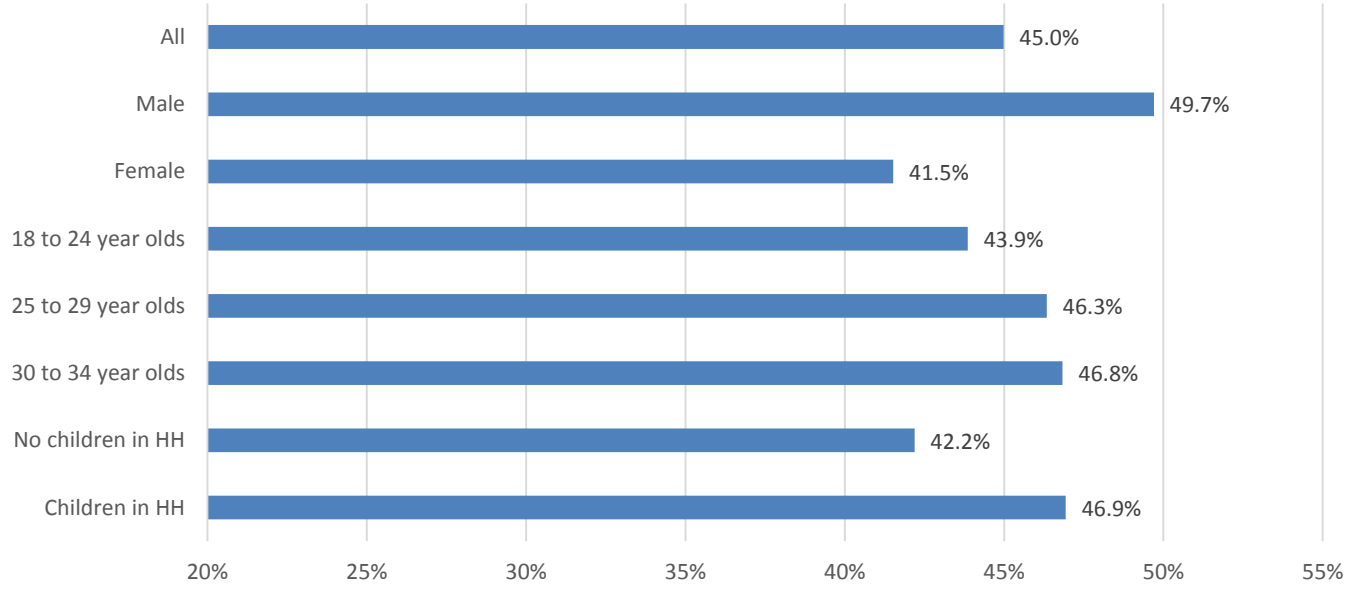
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Figure 29: Remote Medical Diagnosis



Source: *iG*R, 2019

Figure 30: Remote Medical Diagnosis – Privacy Concern

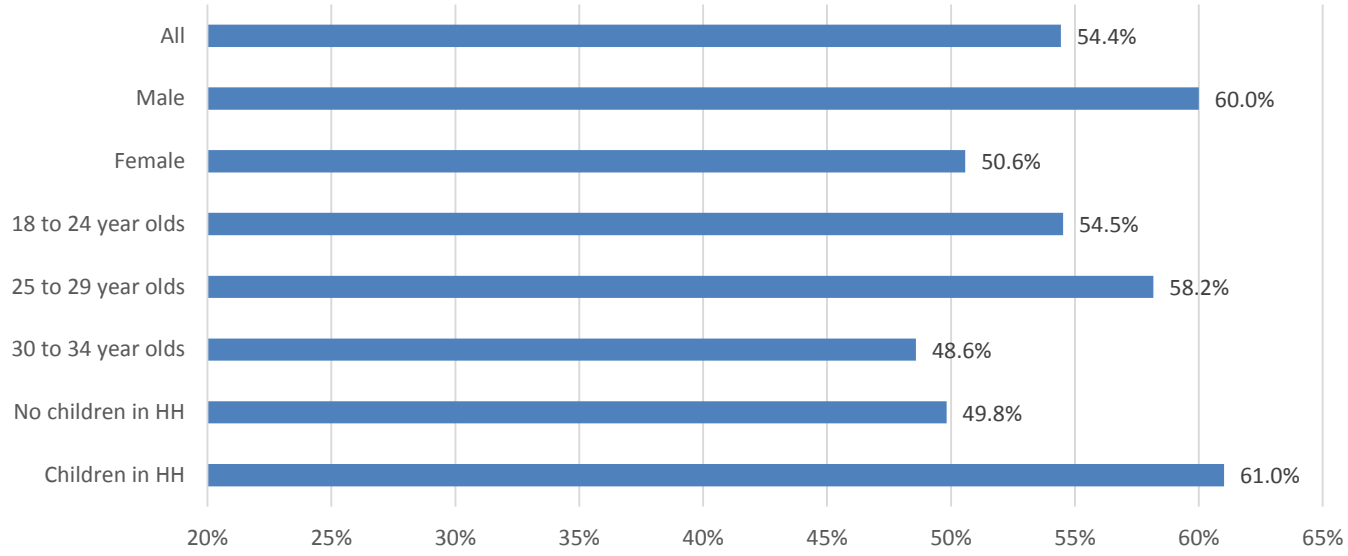


Source: *iG*R, 2019

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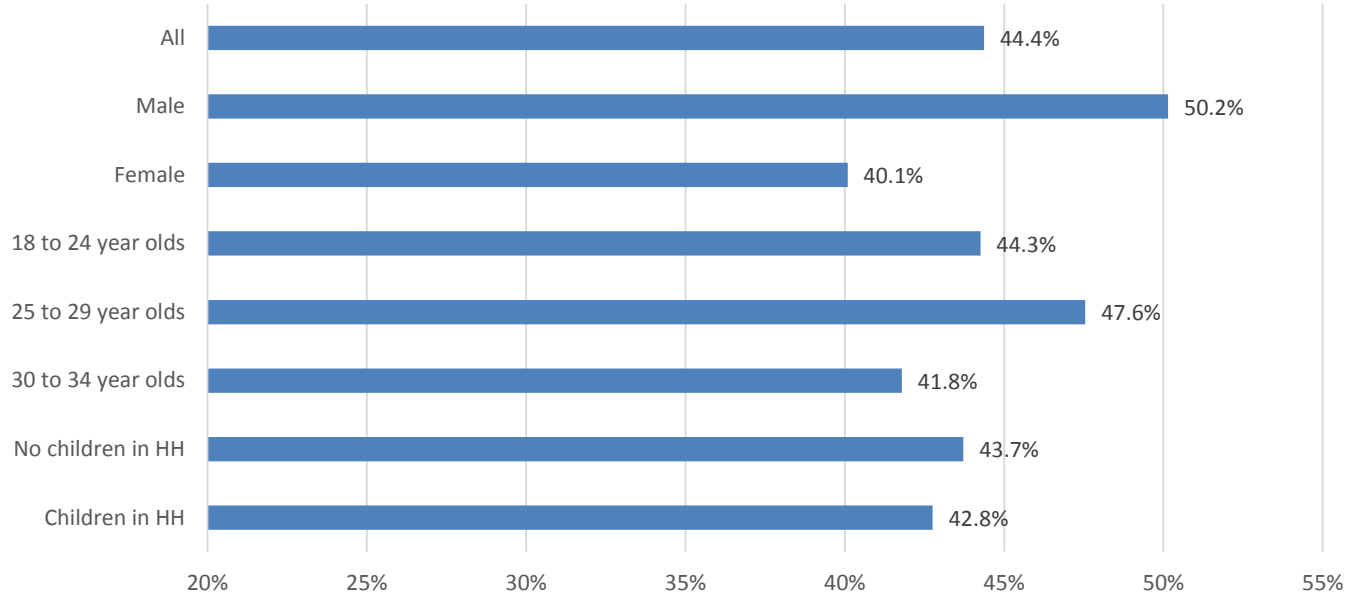
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Figure 31: Automatic Tow Truck and Police Notification in the Event of Accident



Source: *iGR*, 2019

Figure 32: Automatic Tow Truck and Police Notification in the Event of Accident – Privacy Concern

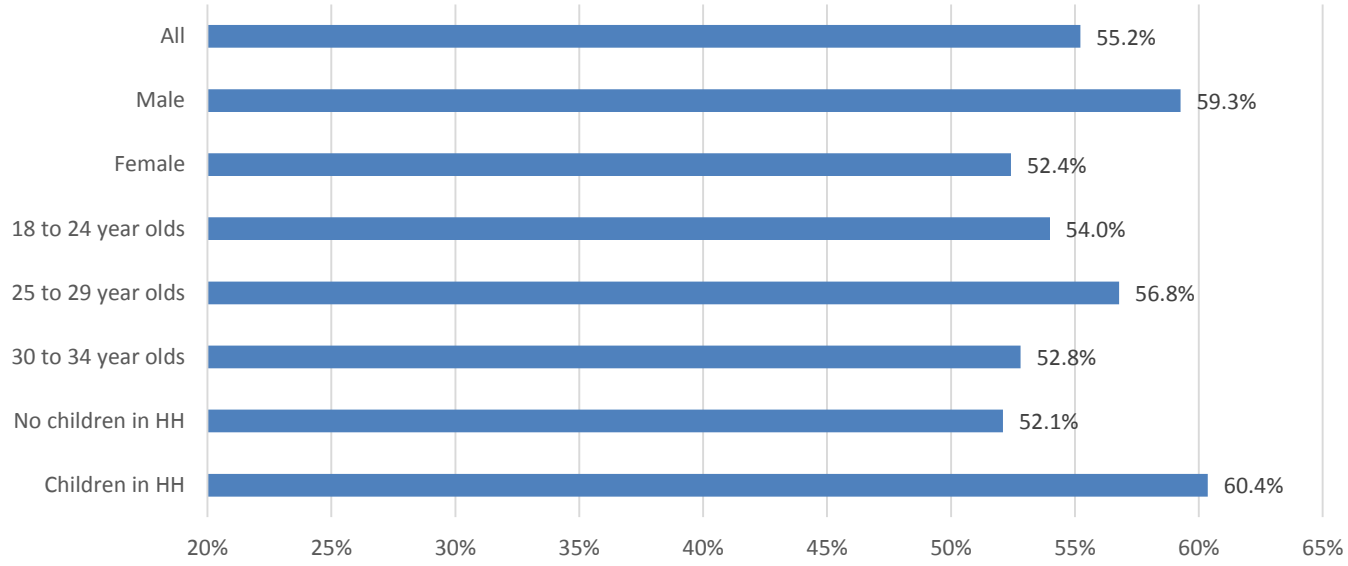


Source: *iGR*, 2019

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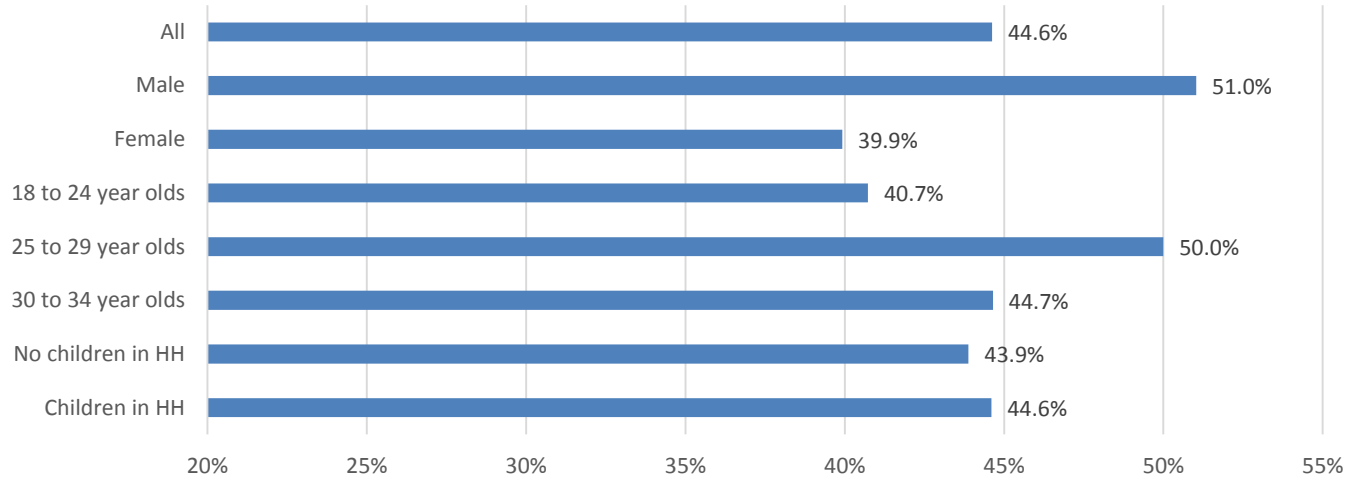
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Figure 33: ER Doctor Access to Patient in Ambulance



Source: *iG*R, 2019

Figure 34: ER Doctor Access to Patient in Ambulance – Privacy Concern

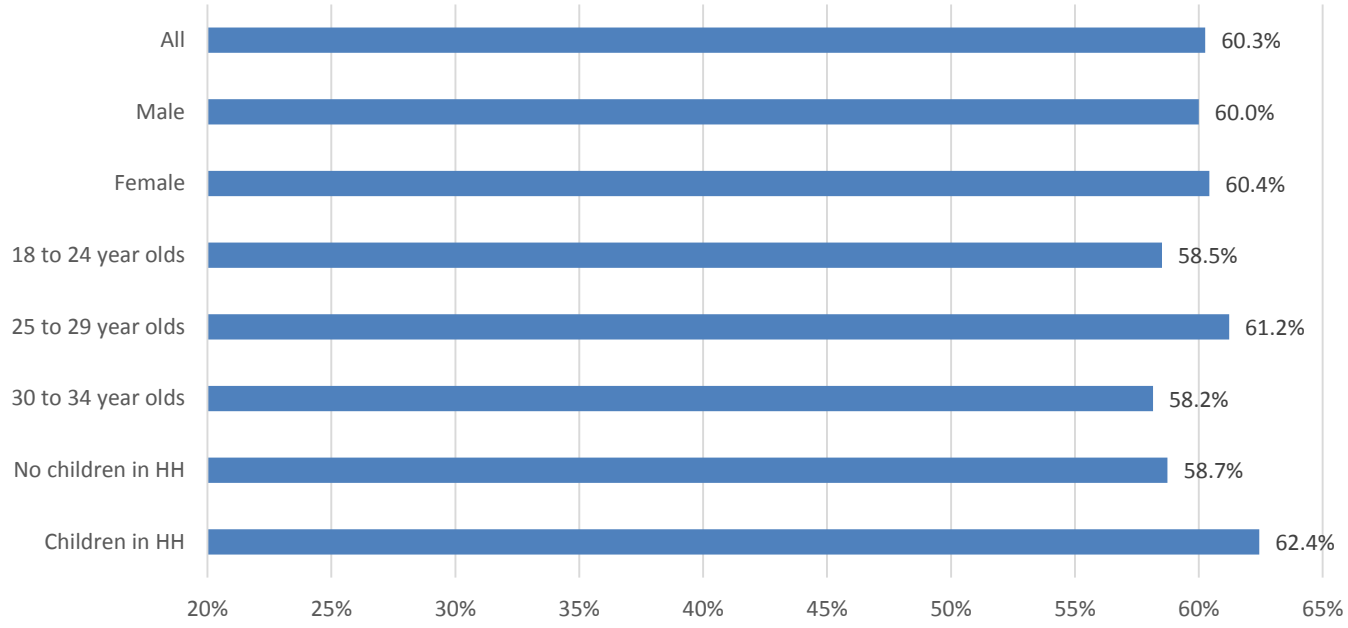


Source: *iG*R, 2019

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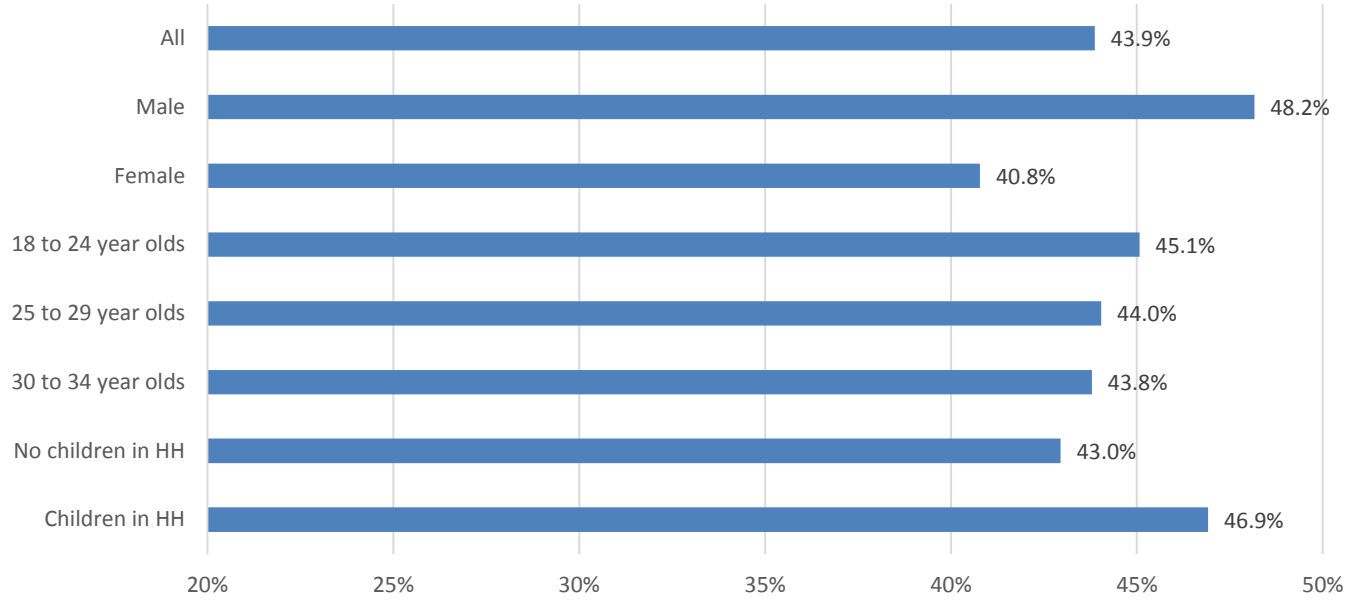
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Figure 35: Public Safety Real-time Municipal Information



Source: *iGR*, 2019

Figure 36: Public Safety Real-time Municipal Information – Privacy Concern



Source: *iGR*, 2019

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